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The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by

LEON GASTER

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OFFICIAL ORGAN OF THE
Illuminating Engineering Society.
(Founded in London 1909.)

SPECIAL SEARCHLIGHT NUMBER.

This number contains the complete account of the Discussion on **Searchlights: their Scientific Development and Practical Applications,** opened by **Mr. P. G. Ledger** at the last meeting of the Illuminating Engineering Society, on January 19th, 1915.

There are Special Contributions on this Subject by **Mrs. Hertha Ayrton, Mr. A. P. Trotter,** and **Professor A. Blondel.**

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EDITORIAL.

Searchlights: Their Scientific Development and Practical Applications.

The discussion on searchlights at the last meeting of the Society was a very timely and interesting one. As explained by the Chairman in opening the discussion, the Council had wisely decided that there should be no comment on the arrangements made by the authorities in regard to military matters. The various speakers, therefore, necessarily confined themselves to scientific and practical points of general interest, and refrained from giving specific information on some points on which a great deal might have been said in ordinary circumstances.

Nevertheless, the discussion was most instructive. Searchlights, besides playing an important part in military operations, have a wide field of utility in times of peace, and there is great scope for invention in dealing with the new problems that are constantly arising in this highly technical field of work.

The general impression gathered from the discussion, indeed, is that the subject has been somewhat neglected in the past. The literature is

extremely scanty, and there are many fundamental points on which much difference of opinion is expressed. As in most matters that have to do with illuminating engineering, we find here two sharply-defined aspects, the physical and the physiological. We have to consider, first, the variety of sources now available for searchlights of various kinds. To the electric arc must now be added the oxy-acetylene and oxy-petrol appliances and the half-watt lamp, all of which have possible fields of utility, although the arc lamp naturally gives by far the more powerful light. Moreover, as the contributions of Mr. Eck and Mr. Ritchie showed, even the arc light has not reached its possible limit of efficiency, and the evolution of the new alcohol-cooled type, will be followed with keen interest.

Another entirely different line of research is that of Prof. O. Lummer, of Breslau, who is stated to have obtained an intrinsic brilliancy as much as *twenty-three times* that of an ordinary arc crater, by confining the arc in a chamber where the air is at a pressure of twenty-two atmospheres. The steady temperature of a pure carbon arc at normal atmospheric pressure is given as 4200 deg. absolute. At the higher pressure used by Lummer a temperature of 6090 deg. absolute (which is not far removed from that believed to exist in the sun) is said to have been reached. An interesting point is that special impregnated carbons were used, as ordinary carbon apparently does not lend itself to working under very high pressure. Naturally, at such a temperature as this one would expect a very high luminous efficiency. We await confirmatory researches on Lummer's interesting experiments, and we trust that the matter will be promptly taken up in this country.

Further, in the valuable contribution by Mrs. Ayrton in the present number, it is shown how the choice of carbons and the electrical conditions applied to the arc have an important bearing on its candle-power and steadiness, and it is scarcely necessary to point out that an intermittent flickering arc is highly inconvenient for the observation of distant objects. There are also various precautions to be taken in the manipulation of the arc by the operator—a matter which is dealt with in a very practical fashion by Mr. Trotter in his contribution to the discussion.

But even when we have mentioned the foregoing points we have by no means exhausted the field for study. It is a commonplace among scientific men that before any really systematic researches can be carried out one must be in a position to define accurately and to measure the quantities with which one is dealing. Now the remarks of the various speakers, both manufacturers and those who have independently studied the subject, showed that we are far from having reached finality in this respect. Almost invariably it was admitted that the existing methods of defining the capacities of a searchlight, both as regards range and candle-power, are extremely vague. Prof. Blondel's admirable contribution on this subject will suffice to show the many factors determining range and the need for a scientific method of presentation in preference to vague empirical rules.

As regards the candle-power, we believe that an interchange of opinions among authorities would soon clear up the matter and would lead to an acceptable definition. In any case, it is difficult to see how various appliances can be compared except by their aid; without measurement, how is it possible to determine the degree of any improvement? In research it is the small advance that usually heralds the greater, and it is therefore essential to use methods by which even small indications of possible improvements are recorded.

To reach a decision in regard to specifying range is possibly more difficult on account of the many factors involved, but apparently by no means impracticable. One point on which fuller data would seem to be desirable is the absorption of the atmosphere. Professor Blondel gives a table containing some figures obtained on the coasts of France, and we should like to see similar data obtained in this country. Mr. Paterson, it will be noted, is disposed to think that atmospheric absorption is often confused with quite a different matter, *i.e.*, obstruction of vision by luminous haze, and it is quite possible that many preconceived ideas on the extent of absorption may be wrong. Yet another point that has been persistently discussed for many years is the comparative advantages as regards "penetrating power" of light of various colours. This formed the subject of a long controversy in the early days of the electric searchlight, but, judging from the contradictory views one hears expressed, would seem not to have been completely settled.

Finally, we should like to point out that in addition to the *physical* points mentioned above there are physiological aspects to be considered. The appearance of a distant illuminated object depends on the capabilities of the human eye, its imperfections, and its varying behaviour according to the colour of the light and the brightness of the illumination. Many of these points, therefore, would call for the co-operation of the physicist and the physiologist, and could best be solved through the assistance of the Illuminating Engineering Society.

To sum up, therefore, it appears that there are many points in connection with the theory and practice of searchlights that require investigation, and it would be a good plan if the Illuminating Engineering Society could form a committee to deal with them. Many of the questions involved are of national importance, and such an investigation should receive the sanction and assistance of the authorities.

The utilisation of scientific methods of investigation is an essential element to success, and in the future measures should be taken to ensure that full advantage is taken of our available technical resources. After the war there will doubtless be ample opportunities for the discussion and comparison of the various appliances used by the respective countries. In the meantime we think that the Society has rendered good service by this preliminary discussion, which should stimulate research and lead to the subject being taken up in a more scientific manner.

Street Lighting in War Time.

In our last issue we mentioned that a Committee of the Society had been formed to consider the framing of recommendations on shop-window lighting, so as to enable merchants to comply with the requirements of the authorities, and at the same time to get the best illumination possible in the present circumstances. A series of recommendations has now been drafted and approved by the Council and submitted to the authorities. The recommendations cannot be made public just yet, but we may add that there is every reason to hope that the work of the Society in this direction will be favourably considered, and that in dealing with this technical and difficult subject it will do useful public service.

As the abnormal lighting conditions in London have already lasted for several months, and seem likely to be continued, we think that it would be well worth while to make a similar study of the scientific darkening of the streets. We understand that the Committee of members of the Illuminating Engineering Society which drafted the recommendations on shop lighting, has invited the co-operation of several representatives of the Joint Committee formed to prepare the draft standard specification of street lighting, in order to consider what steps can be taken in this direction. The considerable experience gained in studying the illumination in streets in peace time should be a useful qualification in attacking the peculiar problems that have arisen at the present time.

These problems are essentially technical, and those who have an inner knowledge of the engineering aspects of public lighting can render useful service to the authorities. We are glad to see that the rumoured proposal to extinguish all the lighting of London in the event of the arrival of hostile aircraft, is not to be carried into effect. One can only faintly imagine the consequences of the sudden extinction of the lights in crowded places of entertainment, restaurants, hospitals, asylums, etc., and the plight of pedestrians and vehicles in streets suddenly plunged into total darkness would indeed be unfortunate. The immediate consequences to the gas and electric supply works of a sudden cessation of the entire load would be almost equally embarrassing.

The problem at the present time consists not only in adjusting the lighting to meet the requirements of the authorities as regards military defence, but in doing so in such a manner as to safeguard the public as far as possible from ordinary accidents and to cause a minimum of dislocation to trade and business. We notice that there has been a considerable increase in the number of street accidents during the last four months. It is difficult to trace the extent to which the altered lighting has contributed to this increase, without a close watch on the conditions of lighting at the place and time of each accident, and one should naturally discriminate between the increase of accidents by day and night. If the authorities could arrange for particulars of the lighting conditions to be entered along with the other data regarding each mishap, we feel sure that this step would provide some very useful data for the future. LEON GASTER.

TECHNICAL SECTION.

The Editor while not soliciting contributions, is willing to consider the publication of original articles submitted to him, or letters intended for inclusion in the correspondence columns of "The Illuminating Engineer."

The Editor does not necessarily identify himself with the opinions expressed by his contributors.

A YEAR'S PROGRESS IN ILLUMINATING ENGINEERING.

(A Report presented by the Committee on Progress at the Eighth Annual Convention of the Illuminating Engineering Society (U.S.A.), at Cleveland, Sept. 21–24, 1914; slightly abbreviated.)

(*Concluded from page* 9.)

Photometry.

Heterochromatic Photometry. — The branch of photometry which seems to have had the most attention during the past year is that involving the measurement of lights of different colour. The continued increase in the temperature at which incandescent lamp filaments are being operated has served to accentuate the difference in colour between these lamps and the carbon lamps used as standards.

The study of the flicker photometer has been continued.[98] Some recent experiments have been made indicating that the time element in the growth of colour sensations will explain the reason for weighting red light more than blue-green light when comparing the flicker method with the direct comparison method. On the other hand, a comparison, using the two methods, of two lights of the same resultant colour, one having a continuous spectrum the other made up synthetically, gave the same result in both cases.

The method of employing coloured solutions as filters is well known. A recently described[99] application consists in the use of two wedge shaped glass cells, one of which contains copper sulphate, ammonia and distilled water, and the other iodine, potassium iodide and water. By properly varying the position of one wedge with respect to the other an infinite number of colour changes can be produced in the light falling on the photometer and coming from the comparison source.

Still another method has been suggested[100] for use in heterochromatic photometry utilizing the extreme sensibility of the peripheral retina to brightness contrast. The apparatus includes a vertical screen with an opening at its centre, a series of rotating measuring disks made up of sectors of grey and black in varying proportions, and a photometer bar.

Methods.—The use of fluorescence as an indicator of spectral radiation[101] forms one of the latest additions to the large number of photometric methods. Radiation from the two sources to be compared

98 *Elec. World*, May, 1914, p. 1105.

99 *Sci. et Art de L'eclair*, November, 1914 p. 163.

100 *Elec. Rev. & W.E.*, March 7, 1914, p. 478.

101 *Zeit. f. Inst.*, November, 1914, p. 348.

enters opposite sides of a vessel containing a fluorescent solution of known constitution and absorbing qualities. The point at which the intensity of fluorescence is the same is noted on a moving carriage.

The use of ruled gratings for cutting down intensity in photometric work was developed some years ago. A new modification[102] consists in placing one in front of another with their lines parallel. One grating is fixed and the other is movable by means of a graduated screw in a direction perpendicular to the lines. Thus an effective absorption is obtained from 50 per cent. to 0.

Photo-electric Cell.—The search for an objective photometer which shall take the place of the human eye in measuring light intensities continues but with questionable success.

Abroad a recent study of the photo-electric cell for this purpose gave apparently satisfactory results.[103] Filters were used such that the maximum sensitiveness occurred at the same point in the spectrum as with the human eye. Differences of not more than 6 per cent. were found when measuring the candle-power of various lamps with the cell and with an ordinary photometer.

Another investigation in which an effort was made to use the cell in measurements of sunlight[104] showed that for the measurement of very high intensities, cells of the vacuum type must be used.

The whole question of the practicability of the use of the photo-electric cell in photometry[105] has recently been thrown open, however, in consequence of the results of an investigation of gas-filled cells in this country which seems to show that this cell is not as satisfactory as has been considered. The illumination current relationship, formerly considered linear, is shown to be a highly complicated function of a number of factors.

The results of another investigation[106] indicate that the photo-electric effect of potassium is to be explained by the considerable gas assimilation of this material, *i.e.*, that the existence of gas is a necessary condition for appreciable photometric effect. The correctness of this conclusion is questioned, however, in consequence of some later measurements[107] on freshly cut sodium surfaces in vessels containing residual gases and in others using an extremely high vacuum.

Selenium.—It has been hoped that the selenium cell might be the solution of objective photometry. But no advances in this direction have been made during the past year.

Some work has been done[108] indicating that selenium as such does not have a characteristic sensibility curve, and that differences in the characteristics of light sensitive selenium are purely the result of different crystal formations.

The effect of adding small quantities of tellurium[109] on the sensibility to light of a selenium cell has been studied. It was found that the presence of from 1 to 7 per cent. of tellurium as an impurity in the selenium made a decided difference in the sensibility curves of the cell to various monochromatic radiations in the visible. This is suggested as a possible explanation of the difference found by various observers in the relative position in the spectrum of the maximum of sensibility.

Spectrophotometry.—In spectrophotometry an improvement on the Brace type has been worked out.[110] In the older form changes in intensity on one of the fields were obtained by changing the slit width of the corresponding collimator. To obviate the errors introduced and the elaborate calibration required, polarization has been employed. Two nicol prisms are placed in that one of the collimator tubes the light from which is reflected from the silver strip portion of the dispersing prism. It is claimed that the ordinary difficulties arising from the use of polarization are eliminated.

Standards.—The question of light standards has not been agitated much and but little has been done looking toward the establishment of the ultimate primary standard.

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102 *Jour. f. Gas*, May 16, 1914, p. 457.
103 *Elek. Zeit.*, April 30, 1914, p. 504.
104 *Phys. Zeit.*, June 15, 1914, p. 610.
105 *Astro. Jour.*, June, 1914, p. 428.
106 *Ber der Deut. Phys. Gesell.*, No. 2, 1914, p. 117.
107 *Phys. Rev.*, July 1914, p. 73.
108 *Phys. Rev.*, July, 1914, p. 48.
109 *C.R.*, July 6, 1914, p. 41.
110 *Astro. Jour.*, April, 1914, p. 204.

The use of the Hefner lamp[111] as a standard is comparatively limited in this country, but abroad, particularly in Germany, it enjoys considerable popularity as evidenced by the last report of the Physikalisch Technische Reichsanstalt. During the year 1913, 85 lamps were submitted for test, the total number submitted since the beginning of certification in the year 1893 being 2,079. In addition to the Hefner lamps, 78 carbon lamps were tested for use as photometric standards and 333 metal filament lamps.

At the National Physical Laboratory[112] in England the international comparison, through the United States Bureau of Standards, the Laboratoire Centrale in Paris and the Reichstanstalt in Berlin, of high efficiency incandescent lamp standards has been completed. Measurements made at the laboratory after the return of the lamps showed that their candle-power had remained constant enough to ascribe an accuracy of 0·25 per cent. to the results. The ratios obtained were as follows:—

$$\frac{\text{Reichsanstalt}}{\text{Nat. Phys. Lab.} \times 0{\cdot}9} = 1{\cdot}00_0$$

$$\frac{\text{Bur. of Std.}}{\text{Nat. Phys. Lab.}} = 0{\cdot}99_7$$

$$\frac{\text{Lab. Cent.}}{\text{Nat. Phys. Lab.}} = 0{\cdot}99_8.$$

In these comparisons a colour difference was entailed corresponding to that between a carbon lamp at low efficiency and a tungsten lamp at 1·25 watts per mean horizontal candle.

A portable electric standard for use in measuring the candle-power of gas[113] employs a 4-volt tungsten lamp at 2 w.p.c. and is based on the property of tungsten of rapidly changing its resistance with change in current. The lamp is made one arm of a Wheatstone Bridge and is brought to its rated candle-power by changing a rheostat until the galvanometer gives zero deflection.

Glarimeter.—Under the head of photometry might be mentioned a new instrument called a glarimeter,[114] designed to measure the relative glare or gloss of paper. It was found by experiment that light reflected at an angle of 57·5 deg. from pieces of glazed white paper, calendered black cardboard, calendered white paper and brown solio paper showed a plane polarization 99 per cent. complete. It is a characteristic of most glass surfaces that light reflected from them at this angle, 57·5 deg., is almost completely plane polarized. The instrument, then, was designed to measure the glare by determining the fraction of the light reflected from the paper at an angle of 57·5 deg. which is polarized, the illumination falling on the paper at approximately this same angle.

An interesting test made with this instrument showed that the effect of passing a sheet of unsized newspaper through the calendering rolls twenty-nine times increased the per cent. glare from 27·7 to 64·8.

Illuminating Engineering Societies.

On the subject of photometric methods the German Illuminating Engineering Society has adopted the following definitions:—[115]

"Evaluation of sources of light (special lamps excepted). A source of light is to be evaluated through one of three quantities—*viz.*, (1) mean spherical illuminating power (J_o); (2) mean lower hemispherical illuminating power ($J_\triangledown$); or mean horizontal illuminating power (J_h). Every statement must clearly indicate which of the three quantities is intended.

"From the purely physical standpoint J_o is the most important illuminating power. On practical grounds it is not generally feasible to give up the evaluation of $J_\triangledown$ or J_h, which has hitherto been customary.

"It is therefore recommended that there should be added to the figures for $J_\triangledown$ or J_h the factor for their conversion into J_o."

These definitions have been adopted by the German Association of Gas and Water Engineers and the Institute of German Electrical Engineers.

No conclusions have as yet been reached on the question of nomenclature, but in England the 1910 report of the

[111] *Jour. f. Gas.*, June 27, 1914, p. 622.
[112] *Elec.*, July, 1914, p. 574.
[113] *Proc. Amer. Gas Inst.*, Vol. VIII., 1913, p. 325.
[114] *Elec. World*, March 21, 1914, p. 645.
[115] *Jour. Gas Lt*, July 14, 1914, p. 99.

Committee on Nomenclature and Standards of the Illuminating Engineering Society (U.S.) has been made the basis of a considerable discussion. The results of this discussion, which was participated in by members in other countries, show that there is still a wide diversity of opinion on this subject and emphasizes the necessity of such a body as the International Illumination Commission to which problems of this character may be referred.

According to a published statement of Prof. A. Blondel[116] the effort to establish an illuminating engineering society in France has not been successful. This is apparently due to inability to obtain the moral support of the two large technical societies, one of gas and one of electricity.

International Illumination Commission.

The most important advance in illuminating engineering as a whole came just before the last convention and was forecasted in last year's report.

At the fourth meeting of the International Photometric Commission[117] held in Berlin, August 27th, 1913, a re-organization was effected in which delegates from ten countries participated and formed the International Illumination Commission. The following officers were elected: President, M. Th. Vautier, France; Vice-Presidents, Prof. Hans Bunte, Germany; Dr. E. P. Hyde, America; Dr. L. Kusminsky, Austria; Hon. Secretary, Mr. C. C. Paterson, England; Treasurer, Mr. Weiss, Switzerland. The above officers with two representatives from each contributing country form the executive committee. The representatives of each country are selected by its national committee, if there is one. In default of a national committee societies interested may act directly, but in no case may more than 10 delegates be sent to represent any one country. French was adopted as the basic language.

As a result of this action there is now an authoritative organisation which has for its object the study of questions relative to the lighting industry and the establishment by all appropriate means of international agreement on questions of illumination and to which may be referred such problems as international agreement on a primary standard of light; uniformity of nomenclature in illuminating engineering; definitions, standard photometric methods, etc.

In accordance with the requirements of the Commission a National Committee has been formed in Great Britain[118] composed of five representatives of each of the three technical societies and two from the National Physical Laboratory.

In this country a National Committee had been formed prior to the establishment of the International Commission. It was composed of two representatives from each of the following societies. The Illuminating Engineering Society; The American Gas Institute and the American Institute of Electrical Engineers, while the American Physical Society was informally represented. At a meeting held in February of this year statutes were adopted fixing the membership of the committee as follows: Not more than three representatives from each of the constituent technical societies, one representative from the Bureau of Standards. Any individual who represents the United States as an officer or member of the Executive Committee, or who is a member of any standing committee of the International Commission on Illumination and who is not otherwise a member of the committee. Any individual who actually represented the committee as delegate in attendance at the last preceding meeting of the International Commission on Illumination, and who is not otherwise a member of the committee. Furthermore, when for special reasons the committee desires the intimate co-operation of certain individuals, the committee may elect such individuals as members at large. The terms of all members at large shall expire at the time of the annual November meeting.

Globes, Reflectors and Fixtures.

Since the last report there has been a great increase in the variety of reflecting and diffusing equipment available for lighting. This increase has proceeded along artistic lines, along engineering

116 *Sci. et Art de l'Eclair*, May, 1914, p. 158.
117 *Elec. World*, September 3, 1913, p. 511.
118 *Ill. Eng.* (London), January, 1914, p. 14.

lines, along the lines of special adaptation to particular needs, along the lines of higher and lower priced units and of larger and smaller units.

This increase in variety is particularly noticeable in the semi-indirect field. In selecting units to-day, the selection can be made from a much greater choice than was possible a year ago. There is also a tendency on the part of manufacturers to put out units which approach direct lighting in the results they give, as far as diffusion is concerned, but have the appearance of a semi-indirect lighting unit. This has resulted in the closing of the gap between direct lighting and semi-indirect lighting, as far as reflecting and diffusing equipment is concerned. This emphasizes the need of some other terms than indirect and semi-indirect to apply to lighting systems.

There is a greater tendency in the design of globes and reflectors to have them particularly adapted to architectural needs and particular classes of service. There is a greater variety of units corresponding to particular periods of architecture, and units designed especially for the lighting of churches, hospitals and residences are more in evidence.

From an engineering standpoint the most marked developments during the past year are those involving the use of semi-indirect fixtures for both gas and electric lights and in particular those which have accompanied the advent of the high candle-power and high efficiency gas cluster lamps and the non-vacuum tungsten lamps. The high intensities of these types has made the need for the use of diffusing globes more apparent than ever. In all the units put out for these lamps and the holding equipment for them the ventilation is an important feature and in the case of gas lamps mica sheets are utilized to baffle the heated products horizontally and thereby prevent ceiling discoloration. Mica baffles are also used in gas lamps below the source to prevent over-heating of the glassware. Another point of interest in the tungsten lamp is that the type of filament is much more concentrated than formerly and this is a distinct advantage in that it is possible to obtain higher efficiencies and better distributions of light than were formerly possible with much longer filaments.

In industrial lighting there has been a noticeable tendency in the direction of the increased use of deep bowl reflectors. In street lighting a prismatic refractor has been developed which gives a very extreme distribution of light, the candle-power being highest at about 75 to 80° from the vertically downward direction.

The extent to which the artistic in lamp fixtures has progressed is shown in the production of a dome made of china by a manufacturer of artware and dinner sets.[119]

Mention was made in last year's report of the use of marble in thin sheets to replace glass in lamp fixtures. A big improvement[120] in this material is shown in the production of plates ⅛ in. to ⅞ in. thick (3 to 20 mm.) polished on both surfaces and impregnated with various oils at high pressure and temperatures. In this connection a recent investigation of this material has shown that it is much more translucent than milk glass. The treated marble was found to transmit more red and much more blue than milk glass and is a good diffusing agent even though having a translucency of 40 per cent. The following table shows the results found on the translucency and diathermacy of these marble sheets as compared with various substances.

TRANSLUCENCY AND DIATHERMACY OF VARIOUS SUBSTANCES.

Thickness and material of interposed stratum.	Percentage of light transmitted.	Percentage of heat transmitted.
None	100	100
Treated marble 0·12 in. (3 mm.)	41	5·1
Untreated marble 0·12 in.	21	4·9
Mica 0·02 in.	33	67·5
Clear glass 0·08 in. (2·2 mm.)	92	80·0
Hard rubber 0·01 in. (0·3 m.)		51·7
Writing paper	27·5	4·8
Writing paper oiled ..	55	16·7
Milk glass 0·12 in. ..	25	16·6
Ground glass 0·12 in. ..	76	40·6

A still further extension of the daylight duplication idea[121] is to be found in the development of spectacles made of colored absorbing glass fitted with a dyed film. Different spectacles are designed for different light sources, the materials used being the same as those which would be required

[119] *Elec. World*, May 23, 1914, p. 1166.
[120] *Elek. Zeit.*, February 19, 1914, p. 199.
[121] *Light. Jour.* (U.S.), February, 1914, p. 34.

in order to make an artificial daylight lamp out of the source in question.

Fixtures have also been designed[122] which give a light distribution in a room similar to that given by a window, thus imitating daylight distribution.

The importance of avoiding glare is being appreciated to such an extent that spectacles using colored glass have been devised for attachment to the visor of a baseball player's cap.[123] They are instantaneously adjustable and should be of considerable help to the player when it is found necessary to look directly toward the sun.

Physiology.

The action of radiant energy which enters the eye has been studied,[124] showing the relative amounts of energy absorbed by the various eye media and how the amount of absorbed energy varies with the temperature of the source. Thus it was found that in the total eye about thirty times as much energy is absorbed per lumen of tungsten light as per lumen of light from a black body at 5,000°.

Some work on visual acuity under monochromatic light[125] from the middle of the spectrum as compared with ordinary daylight showed considerable advantage in favour of the former. Results were also obtained indicating that yellow-green eye glasses have a marked effect in improving visual acuity in very bright daylight.

The final results of the extended research of the Glass Workers Cataract Committee of the Royal Society,[126] to find a glass that will cut off as much as possible of the radiation beyond both ends of the visible spectrum and still be transparent to the visible, have been published. Glasses have been prepared that cut off more than 90 per cent. of the heat radiation, are opaque to the ultra-violet and sufficiently free from color to be capable of use as spectacles.

The relative hygienic effects of gas and electricity[127] when used for lighting purposes has again been made the subject of an investigation. The test room used was 2 m. high, 1·25 m. long and 0·6 m. wide, and the results have been variously interpreted depending on whether the critic admits that conditions in a chamber of this size are or are not comparable with those in ordinary living rooms. Another more recent investigation[128] has been made using two rooms of about $57\frac{1}{2}$ cu. m. in size.

Legislation.

Distinct progress in settling a controversy which has been agitated for many years is seen in a recent parliamentary action in England.[129] The question of whether the quality of gas should be judged on a basis of its caloiific or its illu minating power has been for a long time a prolific source of argument and discussion. Charters have been granted recently to two gas companies specifying a calorific standard as a basis for test. Unfortunately there seems to be still a decided difference of opinion as to just how this calorific standard should be specified, but doubtless this will be settled after further research.

In this country the Wisconsin Public Service Commission considered the matter some six years ago, while in New York the question is still under advisement by the New York State Commission, although it has been determined as the result of an extended and very careful series of tests, that there is no definite law between the candle-power and heat unit value of artificial gas. Hence it follows that in changing laws which specify candle-power, it will not be fair to adopt a specific factor to fix the calorific value from the value of luminous intensity.

On the thirteenth of October the results of the work of a commission[130] appointed to fix the units of heat, light, etc., were submitted to the French Academy of Sciences for recommendation before being put into laws for France. The bougie decimale is proposed for the standard of light and defined in accordance with the recommendations of the International Congress held in Paris in 1889.

Legislation with respect to headlights is mentioned under the latter caption.

[122] *Light. Jour.* (U.S.), February, 1914, p. 99.
[123] *Pop. Mech.*, August, 1914, p. 175.
[124] *Elec. World*, October 25, 1913, p. 844.
[125] *Elec. World*, December 6, 1913, p. 1160.
[126] *Phil. Trans. of the Royal Society*, A 509.
[127] *Elec.*, May 29, 1914, p. 309.
[128] *Jour. f. Gas*, July 11, 1914, p. 690.
[129] *Jour. of Gas Lt.*, June 23, 1914, p. 943.
[130] *L'Electricien*, November 8, 1913, p. 304; December 30, 1913, p. 398.

TRANSACTIONS

OF

The Illuminating Engineering Society.

(Founded in London, 1909.)

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

SEARCHLIGHTS:

THEIR SCIENTIFIC DEVELOPMENT AND PRACTICAL APPLICATIONS.

(Proceedings at a meeting of the Society held at the House of the Royal Society of Arts 18, John Street, Adelphi, London, W.C., at 8 p.m., on Tuesday, January 19th, 1915.)

A MEETING of the Society was held as stated above, Mr. A. P. Trotter (V.P.) being in the chair.

The minutes of the last meeting having been taken as read, the HON. SECRETARY announced the names of members in the usual way.

The CHAIRMAN, before calling upon Mr. P. G. Ledger to open the discussion, said it was not expedient that there should be any comments on the arrangements of the authorities with respect to the present War. The object of the discussion was to deal with the scientific development and practical applications of searchlights on general lines.

Among those present were both manufacturers and users of searchlights and it would no doubt be best to hear first particulars of recent improvements, and to discuss their applications afterwards.

The discussion was then opened by Mr. P. G. LEDGER (see p. 53), and the following also took part: Mr. JUSTUS ECK, Mr. W. M. MORDEY, Mr. A. LYON, Mr. T. E. RITCHIE, Mr. F. W. WILLCOX, Mr. L. R. B. PEARCE, Mr. HAROLD SMITH, Mr. S. D. CHALMERS, and Mrs. HERTHA AYRTON.

In conclusion a vote of thanks was passed to Mr. LEDGER for opening the discussion. The CHAIRMAN announced that the next meeting would take place on February 16th, and would be devoted to "Fixture Design in relation to Interior Decoration."

NEW APPLICANTS FOR MEMBERSHIP IN THE SOCIETY.

The names of the following applicants for membership have been duly submitted and approved by the Council, and were read out by the Hon. Secretary for the first time at the General Meeting on December 1st, 1914.*

In addition, the names of the following applicants have been duly submitted and approved by the Council:—

Dickinson, H., *M.I.E.E.*	City Electrical Engineer, Greenwood, Victoria Park, Wavertree, LIVERPOOL (1).
Eyers, C. F. C.	Chief Gas Examiner for the State of New South Wales, George Street, SYDNEY, Australia (1).
Ledger, P. G., *M.I.E.E.*	Electrical Engineer, Messrs. Siemens Bros. Dynamo Works, Ltd., Caxton House, Westminster, LONDON, S.W. (1).
Pitman, C. H.	Lighting Engineer (The General Electric Co., Ltd.); 166, Stockwell Park Road, Brixton, LONDON, S.W.
Tye, L. M.	Lighting Engineer (Holophane Ltd.); 11, Watford Villas, Battersea Park, LONDON, S.W. (1).
Wigham, J. C.	Chief Engineer of Edmundson's Electricity Corporation, 11, Tothill Street, Westminster, LONDON, S.W. (1).

* *Illum. Eng.*, Jan. 1915, p. 12.

The Illuminating Engineering Society

(Founded in London, 1909).

NEXT MEETING.

The **next meeting** of the Society will take place at the House of the Royal Society of Arts (18, John Street, Adelphi, London) on **Tuesday, February 16th, 1915, at 8 p.m.**, when a discussion on the **Development and Design of Lighting Fixtures in relation to Architecture and Interior Decoration** will be opened by **Mr. F. W. Thorpe.**

THE EYESIGHT OF SCHOOL CHILDREN.

At a meeting of the Council of the Illuminating Engineering Society in the United States on January 14th, 1915, Mr. M. Luckiesh presented the manuscript of a paper entitled "Safeguarding the Eyesight of Children." This paper, with some seventeen or eighteen slides, is to be used for a lecture on school lighting for presentation at meetings of school authorities throughout the country.

SEARCHLIGHTS:

SOME NOTES ON THEIR SCIENTIFIC DEVELOPMENT AND PRACTICAL APPLICATIONS.

By P. G. Ledger.

Introduction to Discussion at the Meeting of Illuminating Engineering Society held at the House of the Royal Society of Arts (John Street, Adelphi, London, W.C.), at 8 p.m., on Tuesday, January 19th, 1915.

A DISTINCTION should be drawn between sources of light intended to serve as *beacons, i.e.* to be visible and to serve as a guide to distant ships, and *searchlights* which are intended to illuminate and reveal distant objects. The former in general utilise a beam of light concentrated over a small angle, the latter may have to be visible over a wide area. The distinction is sharply defined in the case of motor-car headlights and side-lights. In the case of coast lights intermediate conditions exist, since the area to be covered, although considerable compared with that over which a search-light operates, is often restricted to some extent. In some cases, for example, a travelling concentrated beam may be more efficient than a stationary light of less brilliancy; nevertheless its main function is usually to be seen by vessels rather than to illuminate them.

While searchlights and beacons both presumably come within the scope of this discussion, it is proposed to limit these opening remarks mainly to searchlights. However, there are many optical problems that apply to both.

For the benefit of those to whom such apparatus is unfamiliar I may explain that the searchlight is an apparatus for throwing a beam of light to a considerable distance in order to illuminate distant objects at night, and thus to enable them to be seen. In order to enable the beam to reach the maximum distance, the rays composing it should be approximately parallel to one another, as, if there is much dispersion, the distance that the beam can carry soon diminishes. The projector consists of two main parts, namely, a source of light and a reflector, which latter collects the diffused rays proceeding from the source and projects them forward in a parallel beam.

The chief essential in a searchlight is a source of great intrinsic brilliancy and small dimensions. Strictly a "point-source" would be necessary to get an absoluetly parallel beam, but in practice there are few instances in which a beam of smaller divergence than 2 to 3 degrees is desirable. (Otherwise it would take too long to search a given area.)

For searchlights of high power such as are used for maritime work, therefore, the electric arc is invariably used, since its intrinsic brilliancy (estimated at about 200,000 candles per square inch) is incomparably higher than any other artificial illuminant. For motor-car and locomotive headlights bunched incandescent filaments have been used, and it is possible that the half-watt lamp will lead to developments in this direction, and for cinematograph work. There is also the oxy-acetylene incandescent light to be considered. For beacon lighting, on the other hand, where a source of larger dimensions and moderate intrinsic brilliancy is often permissible, incandescent oil and acetylene systems are sometimes used.

In the modern searchlight the beam is obtained merely by placing the arc at the focus of a suitable parabolic mirror. Dispersing prismatic lenses are often provided to be placed in front of the searchlight so as to spread the beam over a wider angle and enable a considerable area to be inspected at close quarters. In the case of coast lights for the guidance of ships at sea such lenses occupy a more important position, and their design is often a matter of considerable complexity according to the functions of the light and the nature of the flashing signals to be provided. The mechanism for regulating the arc presents many interesting features, but does not come within the scope of this discussion.

In the earlier searchlights inclined carbons were used, and this method is still followed in small projectors. Nowadays the carbons are arranged horizontally, the positive carbon carrying the crater facing the mirror. The negative carbon is made as small as possible so as to obstruct a minimum of light, and various devices are used to increase its conductivity (such as coating the exterior with copper and introducing a copper wire into the carbon).

The reflector is a mirror of suitable curvature, that is, a curvature the section of which is a true parabola, and at the focus of this the source of light is placed. (See Fig. 1.) It is a well-known property of all the conic sections—and the parabola is, of course, one of the conics—that the normal at any point bisects the angle between the focal distances of the point. The normal at a point is the straight line perpendicular to the surface at that point illustrated in the diagram by the line PN. Therefore, if a line be drawn from the point F, which is the focus, to the point P on the parabolic surface, and if a normal PN be drawn to the surface at the point P, and, further, if another line PD be drawn from the point P, such that the angle FPN is equal to the angle DPN, then the line PD will proceed in the direction of the other focus of the curve. But, as the other focus is at an infinite distance away, the line PD and all similar lines will be parallel to the axis of the parabola and to one another. Now it is, of course, a property of light when reflected from a surface that the angle of incidence, that is, the angle between the incident ray and the normal, is equal to the angle of reflection, that is, the angle between the reflected ray and the normal. Therefore, if a source of light be placed at the focus F of a parabolic mirror, all rays, such as FP, will proceed, after reflection, in a direction parallel to the axis of the mirror and to each other.

Figs. 2, 3 and 4 serve to show the essentials of a typical searchlight. It consists of a barrel mounted on trunnions with suitable arrangements for turning and tipping. The arc lamp furnishing the source of light is placed inside the barrel, the box containing the mechanism being visible beneath; the leads conveying the electric current to the arc lamp can also be seen. The parabolic mirror is placed at the back, and in front is seen a screen made up of parallel strips of plain glass to shut the light in, so that the arc may not be blown out by the wind. On the top of the barrel is a hood for arranging for the ventilation and the passage out of the heated air inside the barrel.

Notes on the Historical Developments of Searchlights.

The history of the searchlight proper does not go back very far, although the use of beacons and coast lights is of early date.

Searchlights of a very elementary character appear to have been used approximately 50 years ago; they were used on French warships in the year 1867, also in the siege of Paris 1870-1871. They appear to have been used by both belligerents. They were, however, of imperfect construction, the mirrors being metallic, which suffered from distortion, corrosion and other defects.

Apparently the first person who made a study of the best means of concentrating the beams of light obtained from an electric arc was a Frenchman, Fresnel, who constructed a special optical apparatus for use in lighthouses. This consisted of a set of concentric prisms, which, acting as a lens, concentrated the light issuing from the luminous point of the heated carbons into a parallel beam. In this case the source of light was behind the lens. Improvements, however, continued to be introduced into the construction of mirrors (where the point of light is in front of the mechanism for concentrating the beam), and more or less complicated methods of approximating to paraboloid surfaces for the reflector were adopted. The reflecting medium, however, was usually silvered glass, as this was found to give more efficient reflection than metallic reflectors.

A simplification in mirror construction was introduced by Mangin, who ground the two surfaces of the mirror to different radii, which had the same effect as a parabolic surface in giving a parallel beam of light. The Mangin mirror had certain disadvantages, however, the principal of which were the liability to

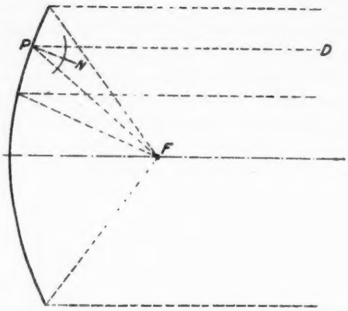

FIG. 1.—Diagram showing characteristic optical properties of parabolic reflecting surface.

FIG. 3.—Twin Searchlight, 24-inch diam. mirror, 100 ampères.

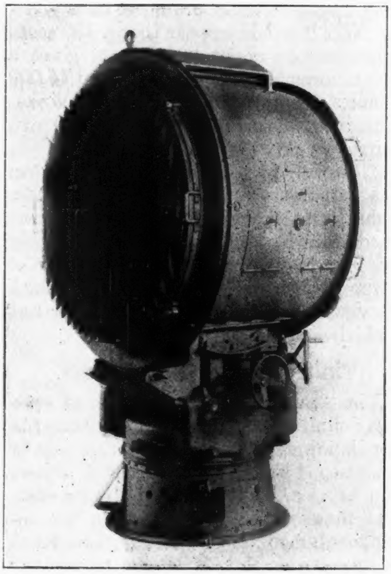

FIG. 2.—Searchlight with special "Venetian blind" signalling shutter; 150 ampères mirror 43 inches (approx.) diameter.

FIG. 4.—Small Stage Searchlight mounted on tripod, 12-inch mirror, 20 ampères.

fracture when heating or cooling owing to the unequal thicknesses of glass, and, for the same reason, was apt to introduce prismatic colours in the edges of the beam. Improvements in grinding machinery, however, have since been made, and there is no difficulty in obtaining parabolically formed mirrors which give parallel beams of great accuracy. The perfection of the mirror is the principal improvement that has been effected in the construction of searchlights.

Reference has already been made to the improvement of using horizontal carbons. Another step has been the introduction of an iris shutter by which the light can be instantaneously and completely shut off so that the searchlight becomes indistinguishable. By the aid of this apparatus the light can be immediately revealed or obstructed, the arc meanwhile continuing to burn normally.

Candlepower of Searchlights.

The candlepower given by a powerful searchlight is very difficult to measure. The mere fact that the volume of light is so large gives rise to difficulty, and even the best arc lamps are necessarily less steady than, for instance, the ordinary glow lamp. Fluctuations in the intensity of the light and the colour take place as the carbons are consumed. Tests may be carried out at a distance of 1000 yards or more, the light being merely balanced against a suitable standard on a photometric bench in the usual way. While this may give some indication of the illumination to be derived from a searchlight, in practice the variable absorption of the atmosphere introduces considerable difficulties. Experiments have, however, been made in very clear atmospheres, and these show that the candlepower varies from about 4,000,000 with a projector 40 cms. in diameter and with electrodes using a current of 20 amperes, to as much as 180,000,000 candles with a 150 cm. projector and a current of 150 amperes.

It may be remarked, however, that, apart from the difficulties of measurement, the candlepower of a searchlight is not theoretically such an indefinite quantity as people sometimes suppose. The total flux of light is clearly a definite physical quantity, and it is only in the case of an absolutely parallel beam (with which one would get the same illumination, except for atmospheric absorption, independent of the distance) that the value to be assigned to the candlepower becomes doubtful. But in practice such a beam is never attained, and even with a divergence so small as 2 to 3 degrees the true centre of the beam can be located at a certain readily calculable distance behind the arc so that the results obtained at distances of 1000 and 2000 yards do not deviate widely from the inverse square law. Naturally, allowance must be made for the true position of the centre of radiation.

The apparently enormous intensities of searchlights are merely a consequence of the light being concentrated in such a very restricted angle far less than would ever be met with in the case of sources used for artificial illumination, even when equipped with a so-called "focussing" reflector. According to data given by Nerz it would appear that a 150 amp. operating at about 9000 watts gives a mean horizontal intensity of about 46,000 candles in the direction of the mirror. The intensification factor of a 150 cm. mirror would be about 4300.

However, for the reasons given above, the candlepower is a very uncertain quantity in practice and is not as a rule specified. The method almost invariably used is to state merely the variety of carbons, the current and voltage at which they will be operated, the diameter and focal length of the mirror.

The Range of a Projector.

The "range" of a projector is an even less definite quantity in practice than the candlepower. By this term is usually understood the distance at which objects can be clearly distinguished by its rays, and many of the figures given for the range of modern searchlights are much exaggerated. Manufacturers, recognising the uncertainties introduced by the state of the atmosphere, are averse from giving a definite guarantee on this point. Results obtained in the clear atmosphere of the Mediterranean have proved quite different from those obtained in the mist-laden atmosphere in this country—even on apparently "clear" nights.

One finds also that people have very vague ideas in their mind when they ask for a certain range, frequently demanding that small objects should be visible which could not under any circumstances be seen by the human eye at the distance specified. It is scarcely necessary to say that the size of the object is an important factor. Another equally important point is the contrast between the object and its surroundings and the amount of light reflected from the object itself. An iceberg such as sank the *Titanic*, for example, is very different in this respect from a ship or a rock. If, therefore, any attempt is made to specify range it is necessary to state at least (a) that the atmosphere is absolutely clear, and (b) that an object of a certain size and a certain colour shall be visible at a certain distance.

As a rough guide one might perhaps say that in clear weather, and setting no limit to the size of an object illuminated, a modern 150 amp. searchlight would carry 10,000 yards.

It is of interest to mention that according to Nerz the radius of action of a searchlight is proportional to the square root of the diameter of the mirror and the fourth root of the intrinsic brightness of the source of light. This relation readily enables the carrying power of various searchlights to be compared.

In connection with the range, one may also refer to the angle over which searchlights can operate. Until recently all that was usually required was to sweep the sea horizontally, and even searchlights for general purposes on land were only required to operate through a small vertical angle. But the coming of aircraft has altered these requirements, and it is now necessary that beams of light should be capable of projection vertically upwards. The war has drawn public attention to this matter, but previously the navigation of the air in times of peace had already been much discussed and the erection of luminous signals, so as to indicate to aircraft their whereabouts, had already been undertaken in some countries. The arrangements of flash signalling by coast lights, though only carried out in a horizontal plane, were already sufficiently complex. To operate such devices in both horizontal and vertical planes would seem a very intricate problem.

As regards the projection of beams of light vertically upwards, there are several distinct methods of achieving this :—

(a) The projector barrel may be given the desired inclination and may be capable of movement both in a vertical and a horizontal plane. (This, however, involves some danger to mirrors, since particles of glowing carbon may fall upon it and damage it.)

(b) Discarding the mirror and replacing it by a lens, in which case the arc could always be below the lens.

(c) Allowing the beam of light to fall on a sufficiently large mirror, inclined at 45°, and capable of rotation in any plane. Although it involves a certain loss of light this would seem to be the most satisfactory method, since the mirror could be readily manipulated so as to direct the beam in any desired direction.

Effect of Atmospheric Absorption and Colour of Light.

It has been remarked that the carrying power of searchlights is very largely dependent on the conditions of the atmosphere, and in very foggy weather it is impossible to use them with very great effect.

It is a matter of opinion how far this effect is dependent on the colour of the light. Some people consider that by imparting a little yellow to the beam the object illuminated can be seen more clearly, but other people do not share this view. From a theoretical standpoint it has been suggested that the red end of the spectrum penetrates the atmosphere more easily than the blue end, and that illuminants rich in the red and orange rays have therefore an advantage in this respect.

In searchlights as ordinarily used on land and sea no attempt is made, as a rule, to alter the colour of the light, and apparently one could only do so appreciably by sacrificing some of the existing rays, *i.e.* by colouring the mirror or using a coloured screen in front of the searchlight. In the case of beacons the conditions appear somewhat different, as one is then concerned with the visibility of

distant lights. I believe that sailors and engine drivers consider that a red light can be seen farthest.

Recent Improvements in Searchlights.

Improvements in the manufacture of carbons have been introduced from time to time, but without some radical change in principle it hardly seems possible to increase very materially the light from an ordinary searchlight. Apart from improvements in carbons, which may be made to give a crater of greater intrinsic brilliancy, there are of course various losses of light in the existing arrangement, *e.g.* the absorption by the mirror, the obstruction of light by the negative carbon, the fact that a certain amount of light never reaches the mirror. But in most cases it will be found that practical considerations set a limit to any possible changes in this respect. For example, it is inevitable that the arc should be screened in and a certain amount of light strike the barrel. The obstruction of light by the small negative carbon is not a serious matter. Curves are available showing the connection between the specific consumption in candles (horizontal) per watt and the total power given to the arc. It is well known that for the smaller sizes of searchlights there is a considerable gain in efficiency as the power is increased. But as one proceeds from 5-10 kilowatts the gain in efficiency is inconsiderable, and one seems to approach a limit at about 6–7 candles per watt.

On the whole, therefore, any improvement with a view to increasing the light would probably have to be made by increasing the brilliancy of the arc crater. Even here it is necessary that the gain in light should not diminish unduly the life of the carbons—usually about 3—4 hours with the most powerful arcs and as much as 7 hours with certain small projectors.

The steadiness of the arc has been improved by the small diameter of the negative carbon, made possible by the use of a copper core. For a 100 amp. arc the negative would be about 13 millimetres in diameter, and the positive about 27 millimetres, so that the shadow cast by the former—especially with the relatively long arc used in modern searchlights—is inconsiderable. Another device that assists in steadying the arc is the use of a horseshoe of soft iron, which is converted into a magnet by the field of the current flowing through the electrodes. This serves to blow the arc downwards and neutralises the tendency to rise upwards.

The chief recent improvements have been in connection with the general manufacture and control of the searchlight—for example, with a view to increasing rapidity of dismantling and facility for handling the various parts so that they may easily be stowed away on board ship.

Another important improvement has been the control from a distance of the movements of the projector and of the iris shutter (if used). As a general principle it is regarded as desirable that an observer should be some distance away from the searchlight so that his eyes may not be dazzled by the proximity of the beam. Accordingly it is arranged for the officer to carry out observations through a telescope, which is so connected with the projector that the latter follows continuously and instantly all the movements of the telescope.

In conclusion, it is probably safe to say that the greatest interest in projectors, at the present moment at all events, on the part of the general public is centred in their employment for anti-aircraft purposes. We, in London, see every night huge beams of light proceeding from various points and traversing the skies, for the purpose of seeking out any of the enemy's aeroplanes or airships, should they decide to honour us with a visit.

As I believe we have here to-night some experts in the use of projectors for this purpose, I hope that the discussion, when it reaches this phase, will bring out any points of interest in connection with this subject which are not regarded as being of a secret and confidential nature.

SEARCHLIGHTS: THEIR SCIENTIFIC DEVELOPMENT AND PRACTICAL APPLICATIONS.

DISCUSSION.

After Mr. Ledger's opening remarks (see pp. 53–58) THE CHAIRMAN declared the discussion open.

Mr. JUSTUS ECK congratulated the Society on bringing forward such a subject as this, which was naturally of great interest and importance at the present time. Mr. Ledger had said that the searchlight in its present form had practically reached its limit of development—at any rate that was how he read the paper—and the curves he had mentioned seemed to demonstrate that it was impossible to get more candle-power per watt or more effective illumination on the object, even if the current in the searchlights was increased.

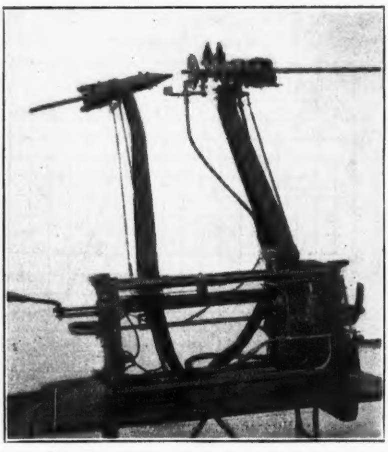

FIG. 1.—Shows arrangement of the small carbons sprayed with alcohol vapour.

This seemed unfortunate, but he thought this was due to the fact that we appeared to have come to the limit of original design in this particular direction.

About a year ago he had the opportunity of seeing the commencement of the developments of a new form of searchlight, which seemed to present many advantages: this had already been described in the American Technical Press, and to some extent it had been mentioned in this country, but it was not referred to by Mr. Ledger. Consequently he had taken the liberty of bringing a few slides, illustrating the new design in its practical form, which showed that the feeding mechanism was similar to that illustrated by Mr. Ledger; but particular attention must be directed to the angle at which the negative carbon approached the horizontal positive carbon: the correct angle had been determined with much care and lengthy experiment. The diameter of the circular carbons was very small, the cross section being about one-fifth of that usually found in searchlights using the same volume

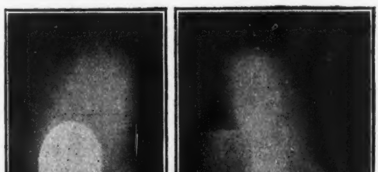

FIG. 2.—Photograph showing nature of crater, and shape of end of carbon.

of current. These carbons were continually rotated, while their points were bathed in the vapour of methylated spirit. In this way much higher specific brilliancy in the crater seemed to be obtained, as well as a more concentrated point of illumination, in a searchlight taking the same current. The vapour

was generated in a little carburettor, heated by the current, placed outside the drum of the searchlight, which was provided with a more powerful ventilating cowl than was usual with ordinary searchlights. A noticeable feature was the entire concentration of the crater on the ends of the carbons, the whole end of the carbons, in fact, being entirely crater.

The polar curve of the lamp was in one plane, similarly shaped to the usual form as given by Nerz, but at the plane at right angle to this was somewhat different, due possibly to the screening by the small negative carbon, or possibly to the passage of the vapour upwards across the face of the crater. The lantern slide (Fig. 3) shows this difference clearly.

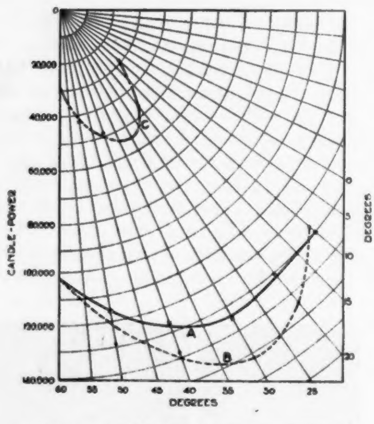

FIG. 3.—Polar Candle-power curves.

Curves A and B show apparent candle-power of lamp with vapour-cooled electrodes. Curve C shows apparent candle-power of lamp with ordinary carbon electrodes.

Current consumption and mirror equipment identical in each case.

Curves A and C taken in one plane and B in another plane at right angles thereto.

In connection with this particular lamp experiments had been undertaken to measure the effective illumination at definite distances. The slide (Fig. 4) shows the measured illumination produced at a distance of 6800 feet from the projector measured along the centre of a field (of 60 minutes of arc radius) the approximate diameter of which at the distance specified is equivalent to 238 feet.

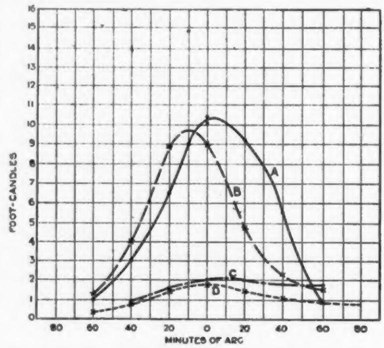

FIG. 4.—Illumination produced at 6,800 feet.

Curves A and B show illumination in foot-candles produced by lamp with vapour-cooled electrodes. Curves C and D that produced by lamp with ordinary carbon electrodes.

Current consumption and mirror equipment identical in each case.

Curves A and C taken in one plane and B and D in another at right angles thereto.

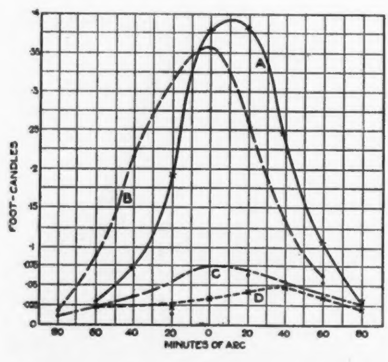

FIG. 5.—Illumination produced at 27,550 feet.

Curves A and B show illumination in foot-candles produced by lamp with vapour-cooled electrodes. Curves C and D that produced by lamp with ordinary carbon electrodes.

Current consumption and mirror equipment identical in each case.

Curves A and C taken in one plane and B and D in another at right angles thereto.

In this case again the measurements are taken with two identical projectors: the curves *a* and *b*, the measurements being taken with the vapour cooled arc at planes at right angles to one another, and the curves *c* and *d*, with ordinary carbons also in the two planes at right angles one to the other. At this distance the average illumination produced by the vapour-cooled arc is about 5·25 foot-candles, while that produced by the ordinary arc is about 1·25 foot-candles, so that the practical utility of the lamp for observing object is about 4·2 times as great.

In the lantern slide (Fig. 5) results are given with the same lamp under the same conditions, but at a distance of 27,550 feet, or practically the limiting distance suggested by Mr. Ledger in his paper. In this case the diameter of the field at the point of measurement is 1283 feet: the average illumination in the case of the vapour-cooled arc lamp is ·185 foot-candles, as compared with the ·035 foot-candles of the ordinary arc; in these circumstances the ratio is 5·2 to 1. The increase in this ratio at the greater distance is of interest, and various explanations can be offered.

Mr. W. M. Mordey said he had been hoping to hear of some radical improvements in searchlights. Mr. Eck had shown how much could be done by comparatively small improvements. Possibly something might result from a consideration of one of the first examples of practical arc lighting in London—the Rapieff lamps at the *Times* office, in the seventies—followed by the better-known Jablochkoff lighting.

In the Rapieff lamp—or in one form of it—the carbons, of which there were two pairs, instead of being in the same line, were so placed as to form a "V," so that both luminous points were more visible and unscreened than with the usual arrangement. It would be interesting to consider whether there would be any advantage in reverting, for searchlight work, to alternating current as used in the Rapieff lamp and thus obtain equally heated carbons. He appreciated that there would be a serious optical difficulty in getting the light into the focus and that it would necessarily be spread out more. He made experiments in that direction many years ago with both direct and alternating current, and the general conclusion he came to—he could not recall the actual measurements—was as follows. Not only did the negative carbon screen the light of the positive crater from the mirror but the useful light was further reduced by the loss of the emission from the negative tip which was directed away from the mirror. The highly heated tip of the negative had an area of perhaps one-fifth of that of the crater, and seemed to be nearly or quite as luminous per unit area. It would be interesting to have the results of any tests that have been made on the subject.

The Nerz curve of candle-power per watt for various kilowatts was very interesting, and showed, as one would expect, that the old Admiralty projector of 80—100 amperes with 65 or later with 80 volts was about right.

The author had not referred to the metal mirrors made by Sir Charles Parsons, which he thought were used a great deal, especially on warships supplied to foreign navies. It would be interesting to learn whether that form, which was less liable to injury than glass mirrors, had been successful in practice.

On the question of colour, Mr. Ledger stated that one could only alter the colour of the light by sacrificing some of the existing rays. He would like to know what had been done in the direction of giving the light its colour by mixing in the carbons foreign substances, such as were used for increasing the length of the arc—for example, could salts of strontium be used to give the desirable red tint to which the author referred?

Mr. Arthur Lyon said the question of candle-power was a very vexed one and commercially a very vital one. Makers were often asked the candle-power of a certain searchlight. He would suggest that if the candle-power of the source were given and also the intensification factor of the mirror, some valuable comparisons could be made. Only that day a man had cabled for the candle-power of a searchlight. He thought the actual light given by the source was referred to, and he cabled back 20,000 candle-power. The answer came

that the customer wanted 2,000,000 candle-power, and seeing at once that he was referring to the projection of the light he guaranteed 37,000,000 candle-power or thereabouts. But what did this information convey?

He wondered whether a unit could not be adopted of a 10 feet square screen at a range of 1,000 yards. Upon this basis data for various ranges at different candle-power could be calculated.

In conclusion, he showed upon the screen a number of slides representing various forms of portable projectors. The first was an oxypetrol projector in preference to a mirror, as the beam must be projected vertically or in any plane. To guard against the dropping of ash from the crater of the arc, when the light is directed vertically downwards, a detachable glass is fitted behind the lens, so that any ash falls on the glass and no material damage is done. He agreed that the optical effect was slightly inferior, as there was a certain amount of chromatic aberration, but the light weight and flexibility was a great asset. The weight was only 60 lbs., and the light was about 2,000 intrinsic candle-power.

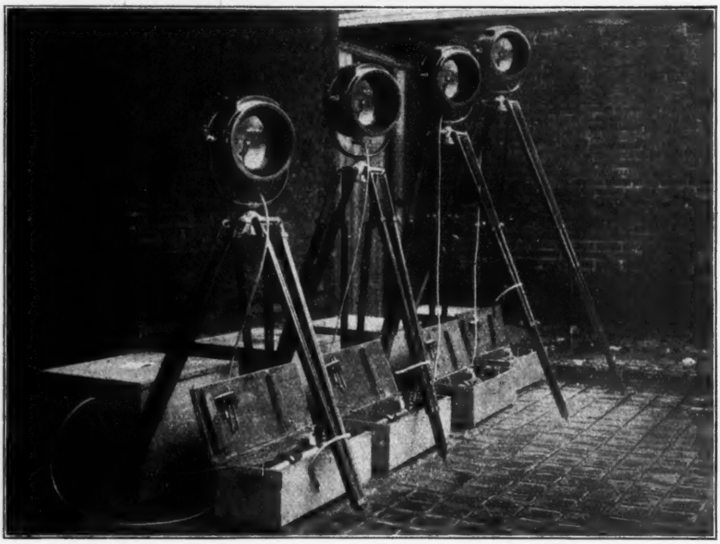

FIG. 1.—Battery of four patent oxy-petrol projectors on tripods complete with transport case for field service. (*Mr. A. Lyon.*)

on a tripod for army field work (Fig. 1). The range was limited, but its portability was an asset. Another was an aero-arc projector of extra light weight constructed for aeroplane work (Fig. 2). The equipment includes a small dynamo with an automatic field regulating resistance to compensate for the variable speed of the engine. The small projector is fitted with a dioptric or Fresnel lens as referred to by Mr. Ledger: this was adopted

Another slide (Fig. 3) illustrated the Stevens-Lyon field signalling lamp: this utilised small metal filament lamps giving 1·1 or 1·2 candle-power, but had a parabolic mirror and was really a miniature searchlight. It had been possible to read Morse signals with the naked eye at the rate of 17 words a minute at a distance of 11 miles, which was very satisfactory.

The final slide (Figs. 4 and 4a) showed a compound reflector with a lens in front,

of sphero-paraboloid form, used in conjunction with a 12-volt battery and half-watt lamps of 150 candle-power.

This gives a parallel beam, as all rays issuing from the source of light are either reflected or refracted into a concentrated beam of high efficiency. This lamp has been successfully used for aircraft signalling.

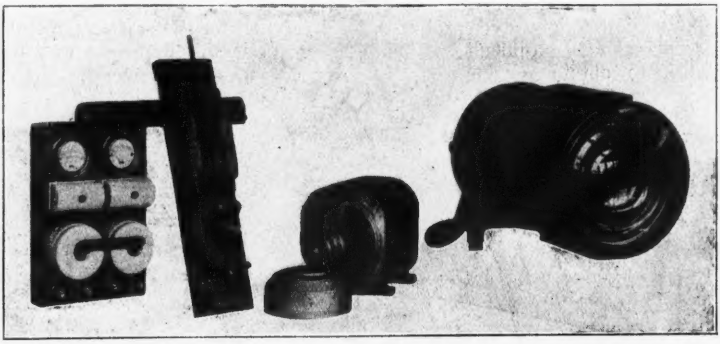

FIG. 2.—Aero-arc projector outfit, with small dynamo and automatic field-regulating resistance. 2,000 candle-power. Weight only 60 lbs. (*Mr. A. Lyon.*)

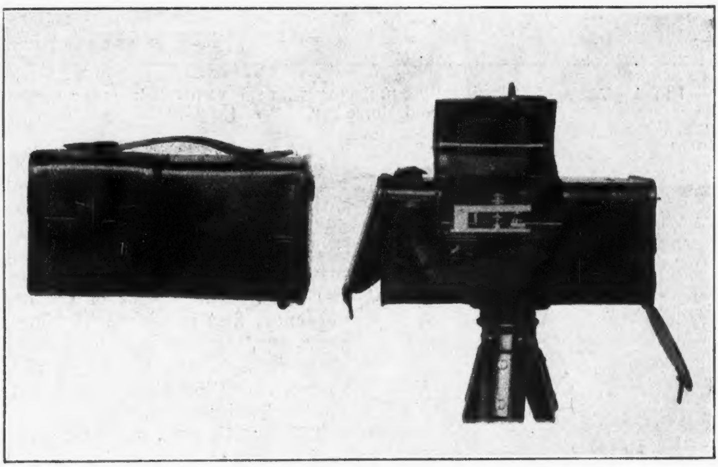

FIG. 3.—Stevens-Lyon patent signalling lamp. (*Mr. A. Lyon.*)

Mr. THOMAS E. RITCHIE welcomed a discussion upon this subject, because we had not yet approached anything like standardisation or uniformity even in the most elemental aspects. If one inquired amongst various makers for a 24-inch projector, one was not at all certain of receiving quotations for identical apparatus. Certain people would handle that dimension correctly, *i.e.*, as the diameter of the mirror, but cases were not infrequent of lower prices being put in based upon the 24 inches being taken as the exterior diameter of the barrel, which would enable possibly a 20-inch mirror to be used with a

corresponding saving in the cost of production. The utility of such an equipment would, of course, be considerably less, but that might not be realised until the purchase had been completed.

Then, again, although information was available more or less readily as to carbon dimensions for any given projector, it was exceedingly difficult, if not impossible, to obtain reliable data as to crater diameters. For these reasons it appeared to him that the Society might add to the good works which it had already accomplished by undertaking, by means of a suitable small committee, the codification of such points. They might, for instance, arrange for the diameter always to be the actual diameter of the mirror, and for the crater diameter to be given, preferably expressed as a fraction of the mirror diameter. Something

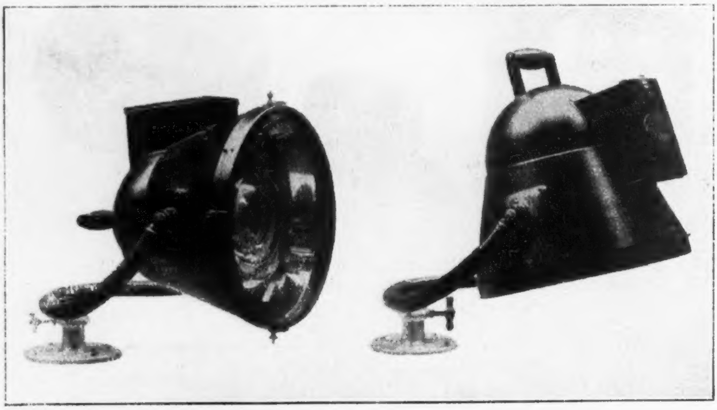

FIG. 4.—Patent electric signalling projectors with sphero-paraboloid reflectors, dioptric lens and Morse key. (*Mr. A. Lyon.*)

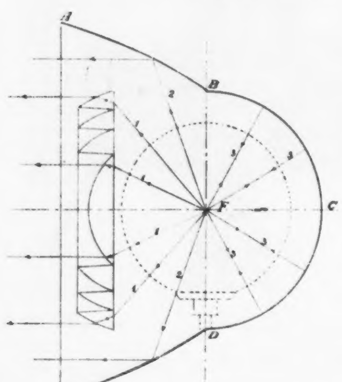

FIG. 4a.—Showing optical system of the signalling projector above. The rays emanating to the right of the focal plane DB return on their own path to the source F and are then collected and refracted by the lens. The rays included in angles AFB, EFD are reflected by the paraboloid surface into a parallel beam of the same axis.

might also be done to encourage greater uniformity in the matter of candle-power ratings, emission and illumination curves, and data of that character.

Turning specifically to the subject matter of the paper, he desired to criticise the use by the author of the data on efficiency, first published by Nerz many years ago, together with his advocacy of range formula, attributable to the same source, which had since been found to be more or less incorrect.

The question of the efficiency of a projector expressed, as in the curve in question, in the candle-power per watt ascertained by dividing the maximum intensity of the rays incident on the mirror by the energy consumption of the arc in watts, had, he considered, an important bearing upon Mr. Mordey's remarks on the question of the colour of the beam.

Those conversant with modern practice would, he thought, agree that we could

now do better than the results shown by the curve in question. It was now easily possible to obtain with an increase from 1 to 5 kilowatts in the energy consumption an increase from 4 to 6½ in the candle-power per watt, and with an increase from 5 to 10 kilowatts an increase from 6½ to 7 candle-power per watt. Above this the specific intensity of the crater could not apparently be raised by increase in current alone.

The colour of the projected beam was, he thought, dependent (apart from chemical alteration of the carbons or the use of coloured mirrors or mediums) upon the intensity of the crater, and was, in the case of projectors of normal type, largely influenced by the considerable area of (comparatively) dull red-hot carbon surrounding the crater proper.

Although the beam from such a projector appeared quite white at night, it had been found that when compared with that from a similar projector having carbons of exactly the same quality, but continuously rotated and vapour cooled, it was in reality comparatively yellow. There was, he thought, substantially the same type of change in the colour of the emitted light rays as there was between the carbon filament and the metal filament incandescent lamp, and for much the same reason. It had also been demonstrated that the penetrating value of the beam from vapour-cooled carbon electrodes was distinctly greater.

Tests carried out by the U.S.A. Naval Authorities at Brooklyn had shown that upon the same evening, at the same hour, and therefore under as nearly as possible precisely similar atmospherical and other conditions, it was possible to pick out and hit a target at night at a very much greater distance and considerably more easily than with projectors similar in size and capacity of the ordinary type.

The exact distance varied with the target used and might not be stated. It was, however, of the order of from three to four miles. The height of the observation point might not be given, but was not abnormal.

Other advantages accruing from the use of the small diameter rotating carbon were the practical elimination of troubles due to "wandering" of the arc and "building" of the carbons; the fact that difficulties incidental to certain impregnating and other processes involved in the manufacture of high-grade carbons could be more successfully overcome in the case of those of small diameter the quality of which was therefore usually higher; the possibility, owing to the more complete combustion at the higher temperature, of varying the colour of the beam by the more successful use of either homogeneously impregnated, or chemically, or metal, cored, or coated, carbons; and, in the case of high angle work—as in searching for aircraft—the considerably reduced risk of the mirror being damaged by the falling from the crater of fragments of white hot carbon.

The author had also referred to the question of glare in its relation to the use of searchlights, and had quite rightly mentioned that with the ordinary type of projector of from 80—150 amperes it was necessary for the observer to be at least 20—30 feet away, otherwise it was not possible to obtain anything like good visibility. This was a point of considerable moment, as the trouble was one very difficult to overcome. Although the beam from such a projector appeared at a distance of a few feet from the front glass to stand out very clearly, a handful of sand thrown into the air showed that the rays of light extended over a very large radius outside the beam proper, and it was undoubtedly those rays which were responsible for the experience of glare from which the operators of such projectors usually suffered.

This defect with the average projector was, of course, well known to the U.S.A. Naval Officials, and it was, therefore, worthy of note that they should have found that with the vapour-cooled projector the absence of this glare was one of the noticeable effects, and that the man actually operating the searchlight could himself pick out and see an object very much farther away than with the average projector, whilst the observer could get within about eight or ten feet of the projector itself. This would be particularly desirable in heavy weather, because the observer and the operator would then be within speaking, or at

any rate hailing, distance the whole time, an advantage which naval men at all events would readily appreciate.

Further points upon which the author had not touched were the influence of vibration and concussion. In both these cases the smaller and more intense crater was an advantage. The flickering, as observed in the projected beam, was very markedly less, and it was thought that to this fact, coupled with the markedly diminished glare or "scattering," was largely due the increased visibility which was obtained.

As regarded concussion, it was well known that with the average projector, if mounted aboard ship, breaking of the arc occurred every time a gun was fired. In a group of ships those not firing at the moment could keep the object under observation, but in the case of a single vessel the breaking of the arc might afford an agile enemy an opportunity of escaping.

With the vapour-cooled projector such arc breakage did not take place, the projector having under test actually withstood a broadside fired from a Dreadnought without breaking arc.

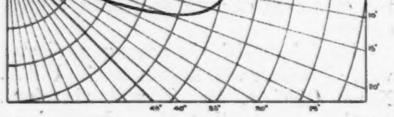

FIG. 1.—Polar Candle-power Curve.
Showing apparent candle-power of searchlight projector for aeronautical, fire brigade, and mining rescue work. Note the wide angle of dispersion.

Mr. Ritchie concluded by showing a number of slides. The first (Fig. 1) was the polar curve of a small projector, taking a current of 25 amperes and operating at an arc voltage of 45 volts, which was specially suitable for aeronautical, fire brigade, and mining rescue work. The feature of this was, he said, the very wide angle of dispersion obtainable, which was of very great value for the purposes for which the lamp was designed.

The next slide (Fig. 2) illustrated a method of testing which enabled one to obtain reliable photographic data as to the character of beam produced under any given conditions, and by means of which, coupled with one or more "receiving" stations, one could also secure definite illumination measurements and so *know* exactly what one was in a position to offer. Such testing stations also enabled one to investigate closely such problems as that of atmospheric absorption, the effect of mist in the scattering of the light, &c., &c.

The final two slides (Figs. 3 and 4) showed the appearance of the projector, which was removable from its stand, which also folded and could be packed away into quite a small space. Such projectors had, he stated, been successfully used for fire brigade work for several years, and were now beginning to be employed for mining rescue work.

Mr. F. W. WILLCOX presented a table, as shown on p. 68, giving some values obtained with metal filament lamps when used in searchlights of smaller ranges. Metal filament lamps with concentrated filaments, by reason of their advantages of simplicity and adaptability, have an increasing field of use in connection with all kinds of searchlights for amperes below 20 to 10 and have been largely used in locomotive headlights—especially in America. They are also used on motor boats, yachts, tramcars, automobiles and aeroplanes. Searchlights using metal lamps are also employed, as Mr. Ritchie had said, by fire brigades at night, and also for advertising work—for the "flood lighting" of buildings and of hoardings at night. The filaments of these lamps are made in a concentrated form of spiral, and they are replacing, in a large measure, searchlight arcs in sizes below 10 to 20 amperes. Certainly very much better results had been obtained with these metal filament lamps on locomotive headlights than with small power arcs, and the introduction of the "*half-watt*" lamp has greatly promoted the value and

FIG. 3.—Exterior view showing method of attaching connecting plug and flexible.

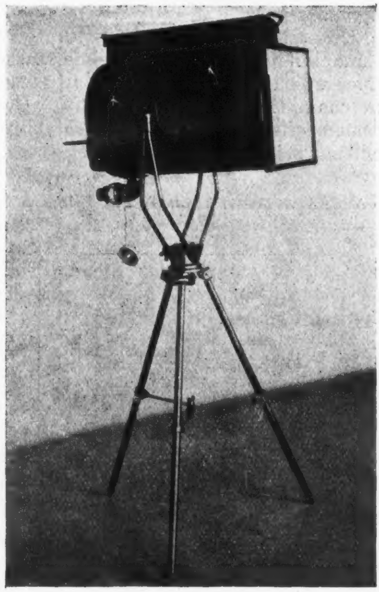

FIG. 4.—Exterior view of projector showing remarkable dispersing lens.

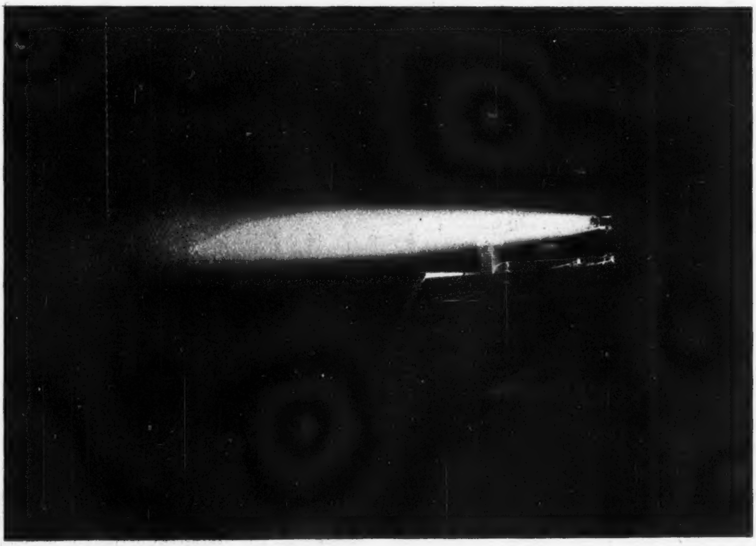

FIG. 2.—Showing testing station on roof (sending end). (*Mr. T. E. Ritchie.*)

application of metal lamps for searchlights.

The table presented herewith gives some interesting data and information upon which inquiries are frequently made in connection with searchlights. Customers often ask how far a searchlight will enable a man to pick up or observe an column in the table gives data on this interesting question.

The candle-power of the headlight is frequently asked for. This may be the maximum beam candle-power or the average beam candle-power over a certain spread. The table answers these questions in columns 4 and 6.

VALUES WITH SEARCHLIGHTS EMPLOYING METAL FILAMENT LAMPS—CONCENTRATED FILAMENTS.

Type of Headlight.* Diam.	Type of Headlight.* Focus.	Particulars of Lamps.	Maximum Beam c.p.	Spread to 10 per cent. maximum intensity.	Average Beam c.p. (across horizontal diameter of beam) over spread to 10 per cent. of maximum intensity.	Maximum pick-up distance. Man in dark clothes.	Multiplying Factor.
9 5/16"	2¾"	6volt 108 watt G-30 Headlight ..	900,000	5 deg.	492,000	2870	6000
		34 volt 250 watt G-30 Headlight ..	300,000	8 deg.	165,000	1820	840
		110 volt 500 watt G-40 Stereopticon ..	700,000	9 deg.	355,000	2500	980
16"	3"	6 volts 72 watts G-25 Headlight ..	550,000	5 deg.	270,000	2290	5240
		34 volt 100 watt G-25 Headlight ..	100,000	8 deg.	55,000	1200	800
		34 volt 250 watt G-30 Headlight ..	250,000	8 deg.	137,000	1700	700
		110 volt 250 watt G-30 Stereopticon ..	225,000	8 deg.	129,000	1760	721
		110 volt 500 watt G-40 Stereopticon ..	650,000	8 deg.	379,000	2460	630
12⅞"	3"	6 volt 72 watt G-25 Headlight ..	325,000	5 deg.	175,000	1860	3090
		34 volt 100 watt G-25 Headlight ..	60,000	8 deg.	33,000	977	480
		34 volt 250 watt G-30 Headlight ..	150,000	8 deg.	82,000	1410	420
		110 volt 100 watt G-30 Stereopticon ..	27,000	8 deg.	15,000	708	337
		110 volt 250 watt G-30 Stereopticon ..	125,000	8 deg.	69,000	1305	400
12¾"	1⅝"	6 volt 36 watt G-18½ Headlight ..	126,000	3½ deg.	68,000	1310	2520

* Furnished with Polished Aluminium or Silver-plated Brass Reflector.

obstacle. The answer to this question depends on a great many conditions such as the contrast between the object and the background. For example, a man dressed in white can be seen against a dark background 1·7 times as far as one dressed in medium-coloured clothes, and the latter in turn can be picked up 1·3 times as far as one dressed in dark clothes. The condition of the atmosphere affects the "pick-up" distance, as does also the colour of the light. Next to the last

The last column in the table gives the multiplying factor, which term is frequently used in headlight specifications, and gives the ratio between the candle-power of the light source itself and the candle-power of the resultant beam. An important factor, taking the relative spread and intensity of the resultant beam, is the concentration of the light source at the focal point of the reflector. A concentrated light source out of focus may be just as bad as one having little or

no concentration. In order to show the enormous effect on the beam produced by proper and improper focussing, the following diagram (Fig. 1) is presented.

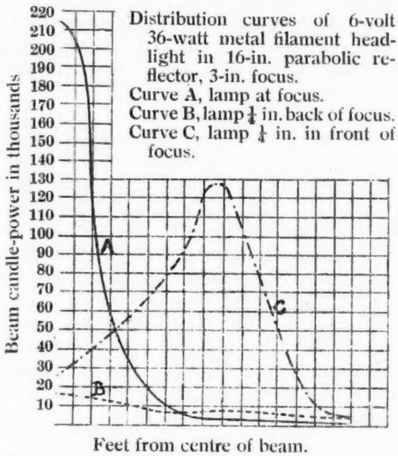

Fig. 1—Searchlights with Metal Filament lamps Showing effects of proper and improper focussing of lamps.

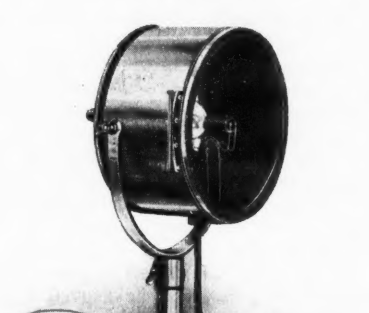

FIG. 2.—Incandescent electric lamp mounted in searchlight.

Here we have the difference between 215,000 maximum beam candle-power (Curve A) when the lamp is in focus as compared to 17,000 candle-power (Curve B) when the lamp is ¼" in rear of its proper focussing position. It is very important therefore that headlights employing metal filament lamps should permit adjustment so as to secure accurate focussing, which should be always done with each installation of lamps with extreme care to obtain the maximum effect.

Mr. L. R. B. PEARCE remarked that it was not quite accurate to say that with the Siemens twin arc lamp it was possible to train each lamp independently, to sweep in one direction with one and in another direction with the other. As a matter of fact the sweeping movement was comparatively limited, taking the lamps separately; but taking the two together, of course an entire circle could be swept. Reference had been made to the use of metallic salts, such as salts of strontium and calcium. He did not know whether that would be useful; it occurred to him that such ingredients might affect the resistance of the electrode, cause "spurting," and injure the surface of the mirror unless very carefully mixed.

Another speaker referred to the use, by the French Government, of small voltage metal filament lamps which were overrun to the extent of over 100 per cent., enabling a very brilliant light from a comparatively small source to be obtained.

It would be interesting to know whether an advantage in definition could not be obtained by concentrating several searchlights from different directions on the same object. Would it be possible to increase the range in this way?

Mr. H. SMITH referred to the report of a complete series of tests on searchlights and their carbons made by an American officer, Captain J. C. Ohnstad, of the U.S.A. Coast Artillery Corps. The report is given *in extenso* in the September, 1914, number of the *Journal of the United States Artillery*. The Americans give great attention to coast defence, probably more than any other nation, and their experience with large searchlights is therefore very considerable.

The CHAIRMAN said that a message had been received on the telephone that all officers of the Admiralty attending the lecture were desired to leave at once for their respective stations.

Mr. SMITH, continuing, said the officer in question was instructed to experiment with the existing naval searchlights, sizes 24″, 30″, 36″ and 60″, and to make tests relevant to the selection of carbons and to convenience in working. He found that by attention to the nature of the carbons the efficiency could be increased by quite 50 per cent., giving in this connection many interesting results and curves. As the carbons burnt, both of them approximated to definite shapes, and the nature of these vitally affected the efficiency of the searchlight. The shapes which best suited the normal type of reflector, which subtends 120° at the arc, were quite definite; the positive should be roughly speaking as basin-shaped, and the negative as pointed as possible. With such shapes the zone of maximum brightness is moved from the usual position at 40° from the axis fully ten degrees further out, giving the maximum light emission to the outer annuli of the mirror, which occupy most of its area. This efficient working on the outer part of the mirror is a counterpart of the optical advantage of the Mangin contrasted with a spherical mirror.

In view of the importance of a suitable form of crater, Captain Ohnstad recommends that the carbons should be manufactured moulded to the correct forms, thus obviating the initial inefficient period during which they burnt to shape. In his complete specification for searchlight carbons he includes full dimensions of the shapes recommended.

The use of special carbons, emitting light which would more readily pierce a misty atmosphere, was found inadvisable. In practice the flame thereby produced obscured the incandescent crater, markedly decreasing the optical efficiency, while the emanations fouled the mirror surface, and caused headaches to the operators in the searchlight casements.

The HON. ASST. SECRETARY then presented a communication received from Prof. A. Blondel (of Paris). (See p. 85.)

He explained that this communication dealt with the determination of the range of searchlights, which depended on a great variety of factors. It was necessary to consider both the physical factors (candle-power of searchlight, nature and colour of object, atmospheric absorption) and also the physiological factors (Fechner's law, acuteness of vision of observer, aid by field glasses, &c.). Prof. Blondel had worked out relations in great detail, connecting these various quantities.

Mr. S. D. CHALMERS: The question of the range of a searchlight is a very difficult one, principally because the range depends so much on the atmospheric conditions. But it is possible to compare the range of two searchlights under identical conditions. The formula quoted by Nerz is, however, incorrect. He says that the range is directly proportional to the square root of the diameter of the mirror and to the fourth root of the brilliancy of the source of light.

This relation would be true if the aim of the searchlight were to pick up a small minute object which would not subtend an appreciable angle at the eye. But in practice the objects are larger and we wish to identify objects on which the detail can be seen by the eye.

In this case objects which subtend the same angle at the eye and are equally illuminated can be seen equally well, whatever be the observer's distance if we can ignore the absorption of the atmosphere. The range is proportional to the diameter of the mirror and to the square root of the brilliancy of the source of light.

Even when the detail to be seen is smaller this law will hold good if the observer be provided with a telescope of suitable magnification and so designed that the maximum illumination of the image is secured.

The theoretical value of the range may be readily calculated from its constructional data. The intrinsic value of the source is about 16,000 candles per sq. cm. and the mirror behaves as if it were of the same intensity as the source. The illumination due to a mirror of radius a cms. at a distance d metres is :—

$$\frac{16{,}000 \times \pi \times (a)^2}{d^2} \text{ metre-candles}$$

to see detail of 1 minute an illumination of

1·5 metre-candles is necessary, and a factor of about $\frac{1}{2}$ is required to allow for the loss of light due to reflection and other losses. Thus :—

$$8000 \times \pi \times \frac{(75)^2}{d^2} = 1\cdot5$$

where d is in metres.

$$d^2 = 8000 \times \frac{\pi}{1\cdot5} \times (75)^2$$

$$= 1600 \times \frac{10\pi}{3} \times (75)^2$$

$$= 3000 \times \sqrt{\frac{10\pi}{3}}$$

$$= 9600 \text{ metres approx.}$$

This is curiously near the 10,000 yards which is quoted in the paper as the maximum range.

In recent years progress in the optical design has been rather in the direction of decreasing the focal length for the same aperture. Although this does not increase the candle-power of the searchlight or its range, it is of use in sweeping for an object. The wider the beam, provided the intensity were maintained, the easier would it be for the eye to recognise objects in the unfamiliar aspects they presented when lit up by a searchlight. As the beam sweeps over the object the eye fails to appreciate what is being seen, but if time were given the eye could correct the first impression and the object might be recognised.

Mrs. Hertha Ayrton and The Chairman (Mr. A. P. Trotter) then took part in the discussion.*

Mrs. Ayrton's valuable contribution dealt, among other points, with the conditions affecting the steadiness and candle-power of searchlights and the choice of suitable carbons.

Mr. Trotter recalled that he had taken an interest in searchlights since 1884, when he earned his first £5 note by doing some work for the Royal Engineers Committee in connection with projectors for fortress work. In 1900 he had the pleasure and honour of belonging to the Electrical Engineers Volunteers, and the principal work was searchlights.

* The remarks of the Chairman and Mrs. Ayrton have been extended and will be found in the form of special communications on pages 78–86.

Mr. Ledger said that his remarks were only an introduction to the discussion, and he was glad that they had led to such useful contributions. It had been very interesting to hear about vapour-cooled arc lamps, and he hoped some further information about that would be published in the Journal. He also hoped that in the printed account of the discussion Mrs. Ayrton would be able to let them have the full benefit of her experience.

Mr. C. C. Paterson was present at the meeting but was obliged to leave early, and has therefore sent in his remarks in writing as follows :—

I quite agree with the author in the contention which he makes that there is essentially no difficulty in rating searchlights, if it is desired to do so, in terms of candle-power. It may be satisfactory for general purposes to define them in terms of the current in the arc and the size of the mirror, but such a rating is not very scientific. One often hears the contention that it is erroneous to speak of the candle-power of searchlights or motor headlights, or similar sources of light emitting a relatively narrow beam. Such a contention, however, will be found to rest on the lack of appreciation of the practical conditions under which such sources of light operate. The beam from a searchlight or a motor headlight is always divergent, and the illumination in such a beam will fall off very nearly according to the inverse square of the distance from the source. Even a searchlight with 2° divergence will be found in practice to follow this rule very closely at all distances from the lamp at which measurements are practicable. I do not think it is quite correct to speak of the candle-power of a searchlight, and I prefer to use the expression "equivalent candle-power," meaning, of course, by this, the candle-power of a lamp which would produce the same illumination at a given distance if put in the place of the searchlight. I do not, however, agree with the author that it is easy to calculate the theoretical point from which the rays from the searchlight appear to emanate, and there is, I think, no justification for tracing back the divergent beam cutting

the outside diameter of the mirror until it comes to a point in the axis, and regarding this point as the virtual centre from which the light radiates.

I should have liked to have discussed at length the question of "Visibility" of objects illuminated by searchlights, but as I am to initiate a discussion on this subject before the end of the session I will reserve until then anything I should otherwise have said on this phase of the question. I would merely remark now that atmospheric absorption is often made responsible for loss of efficiency of searchlights, when what is meant is not I think, absorption at all. Experiments which I have made in conjunction with Mr. Dudding, have shown that on nights which would ordinarily be called fairly clear the atmospheric absorption at a distance of a mile or two miles is relatively little. The difficulty of seeing with searchlights is, of course, that small particles in the atmosphere become brilliantly illuminated, especially in the portion of the beam near to the lamp itself and even when the observer is a little distance from the lamp the trouble does not disappear. These particles become so bright in comparison with the object to be observed two miles away that the eye is dazzled. It is, therefore, merely a question of "glare," and is a kindred phenomenon to that which exists when one tries to read a faintly-illuminated placard with a bright light in one's eyes. It is hardly correct, however, to attribute this lack of ability to see to atmospheric absorption. It is possible that at distances greater than two miles atmospheric absorption may come in to some extent, but the effect will, I think, be found exceedingly small compared with that due to glare.

Mr. J. S. Dow (*communicated*) :— The question of the effect of light of different colours, on which little has been said, is a complicated one. It is generally agreed that the red end of the spectrum penetrates the atmosphere best, but, as the proportion of red rays in an incandescent illuminant is small, this will rarely be a very important factor in the case of searchlights. In the case of beacons, where the visibility of distant luminous points comes in, it might be more important; and if by any means we could get an illuminant of sufficient intrinsic brilliancy producing only orange-red rays *and no others*, it might be more important still.

But there are other factors that seem to favour the use of this end of the spectrum. In the first place the blue and violet rays, owing to their small penetration, are scattered by the atmosphere to some extent. It is said that the luminous haze so produced is distinctly inconvenient to an observer anywhere near the searchlight; it might be less so if the observer is a long way from it.

However, it is probable that a considerable proportion of the rays from the blue end of the spectrum do reach the object illuminated, and this gives rise to yet another effect. Owing to the human eye not being achromatic, most people cannot focus distant blue rays at all sharply. (An experiment described by the late Mr. Shelford Bidwell was as follows: A line spectrum is thrown on the screen; then, as the observer walks away, the spectrum appears to open out like a fan at the violet end, and some divergence is evident right back to the green.) This fact was alluded to by the author in an article in this journal some years ago.* The effect is to cause a slight haze round distant objects, and the blue rays giving rise to this blurred effect may be actually prejudicial. The definition may be improved if they are blocked out altogether.

The easiest way to obscure such rays in a searchlight would be to tint the glass shutter in front of it slightly yellow. It is possible that this would give rise to a distinct gain in visual acuity.

Mr. H. H. Johnson (*communicated*) :— This Society is to be congratulated in bringing forward for discussion such an important subject as Searchlight Projectors: it is difficult to find any other electrical plant or apparatus where so much contention exists concerning the specified requirements and the results actually obtained.

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* The effect of light of different colours on acuteness of vision. *Illum. Eng.* (Lond.), Vol. II., 1909, p. 233.

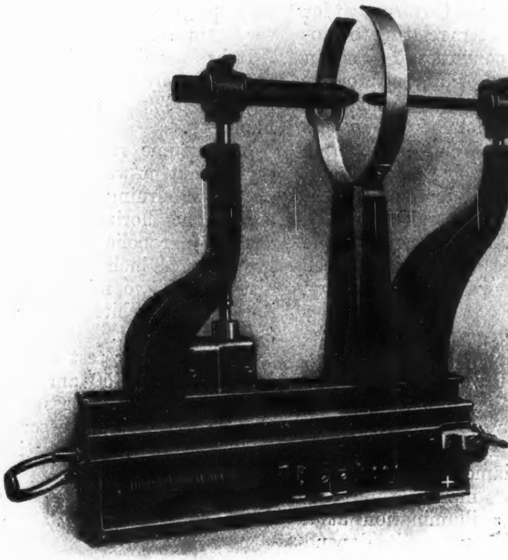


FIG. 1.—Standard horizontal hand and automatic projector lamp of the "Crompton" solenoid type, with an iron deflector fitted to keep the arc central. (*Mr .H. H. Johnson.*)

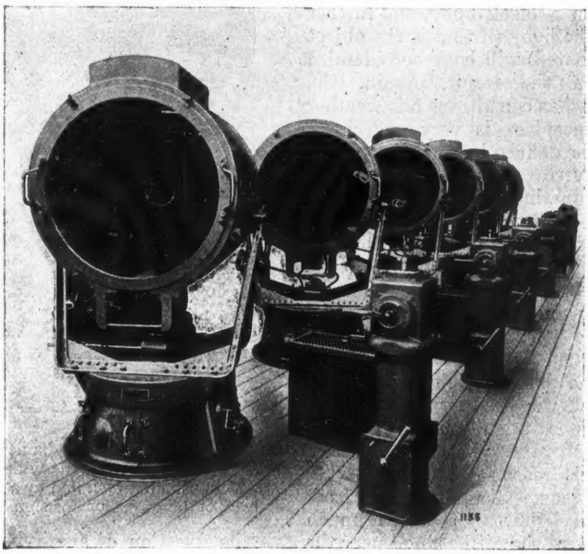


FIG. 2.—Group of 36-in. diameter projectors electrically controlled from a distance, the operating motors being placed at the base of the projectors The controllers and the usual steadying resistance are shown with the projectors. (*Mr. H. H. Johnson.*)

Messrs. Crompton and Co. have been closely connected with the Government for many years on all matters relating to Projector design and construction, and in view of the large number of Projectors at present under construction it would be inadvisable at the moment to discuss many improvements which have been recently made in their design and operation. I can therefore only deal with this subject in a general manner.

It is very surprising to many people that up to the present there has been no serious effort to obtain a recognition by any of the official or technical societies of a reliable basis of comparison of the duties of electrical Searchlight Projectors.

The purchaser of a Projector sometimes specifies the illumination of a definite object at a given distance, or he may call for a Projector of certain candlepower or diameter. Now it is impossible for a manufacturer to guarantee a definite illumination at a given distance, as the test results depend largely upon local conditions, which are quite beyond the control of the manufacturer. For instance, a white buoy can be seen at a much greater distance than a black buoy, and further the size of the buoy (if that is the object to be illuminated) will have considerable influence on the result. Again, the question of what constitutes fair weather or clear atmosphere is very undecided, and cannot be defined in quantities which can be measured.

The illuminating distance of a Projector is not altogether a question of clearness of the atmosphere, but it is very largely controlled by the degree of humidity, as the distance at which one can see does not altogether depend upon the distance which the beam carries, but is governed by the screening of the effect of the haze of light which is formed round the beam, the amount of which depends upon the distribution of light which takes place in the beam. It is for this reason that an observer who stands some distance away from the beam of light can see to a much greater distance than if he stood near the beam, owing to his line of vision not striking the haze screen for some distance. From this it will be obvious that in weather which may be fairly clear to the eye the projector beam may give very poor results if the atmosphere is very damp.

It has been found in practice that the absorption by the atmosphere may be as high as 50% if there is an excess of humidity.

From some recent tests which were carried out, it was found that a 20-inch Projector burning 60 amperes at 50 volts across the horizontal arc, and fitted with a parabolic silvered glass mirror having a 12-inch focus, would carry a distance of two miles and satisfactorily illuminate a white buoy approximately 3 feet by 3 feet.

From another test on a 36-inch Projector burning 150 amperes, and fitted with a parabolic glass mirror with a 17-inch focus, a white screen 6 feet by 6 feet was satisfactorily illuminated at five miles.

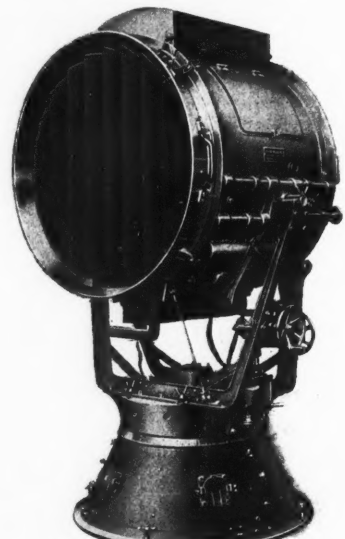


FIG. 3.—Standard 36-in. diameter hand-controlled projector, fitted with a "Louvre" flashing shutter operated by a lever from the back of the projector for signalling purposes.

The question of specifying the power of a Projector in candlepower is very misleading and really meaningless, although certain manufacturers still use the term. If any power of illumination

FIG. 4.—Portable 36-in. diameter electrically operated projector and cable drum for field purposes, as supplied to a foreign power. (*Mr. H. H. Johnson.*)

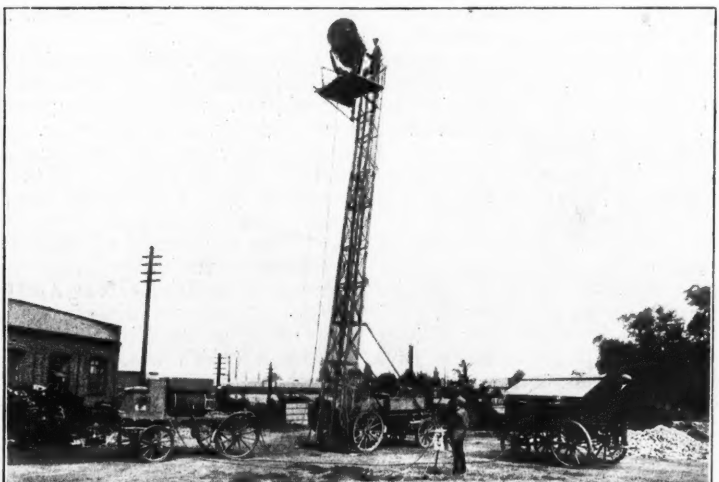


FIG. 5.—Field service military equipment, comprising petrol-driven generator, projector, distributing cable, and tar waggon, all arranged for distant control, as supplied to a foreign power. (*Mr. H. H. Johnson.*)

is to be stated, it should be in lux or other similar unit, but most manufacturers prefer to sell Projectors by stating the diameter and the normal current of the lamp. The diameter should, of course, refer to the mirror and not to the Projector barrel. This appears to be quite satisfactory provided that an efficient mirror is employed (which is usually of the silvered glass parabolic type) and that the carbons are free from impurities.

With regard to metal mirrors, I should like to obtain more information as to the efficiency and their possible commercial use in sizes from 16 inch diameter and upwards. This type of mirror is used in the smaller and cheaper class of Projector, usually of American or Continental manufacture, but presumably the metal mirrors are not often constructed in the larger sizes owing to distortion due to the high temperature and their inefficiency. The advantage of the metallic mirror as regards freedom from breakage has been largely discounted by using glass mirrors fitted with Parsons' Patent system of wired backs and improvements in their suspension and ventilation.

One of the modern improvements in commercial Projectors has been in connection with the Parsons' Split Mirror, which consists of a glass parabolic mirror divided vertically, and hinged in order to give either a parallel beam or a 15 degrees diverging beam with a 5 degrees dark centre so as to conform to the Suez Canal requirements.

Projectors placed on the foremast of the ship or on the chart house can be efficiently operated from a distance either electrically or mechanically.

Projectors for naval and military purposes will no doubt in future have to be capable of control from a distance and of operating with a vertical beam for anti-aircraft purposes.

The accompanying series of illustrations, showing some modern types of apparatus, will no doubt be of interest.

Mr. A. Kitson (*communicated*) :—

Mr. Ledger has given us a very interesting account of the developments of electrical apparatus used for searchlights, and, considering the comparatively short time these have been in use, progress has been very remarkable. His paper, however, deals only with searchlights applicable for disclosing objects at a very great distance.

There is another field in which these high, less intensive lights, such as the acetylene and incandescent oil light, are extremely useful. It must be borne in mind that a very intense beam has necessarily a dazzling effect on the eyes of people on the vessel illuminated. While recently crossing from Holland I was particularly struck by the dazzling effect of the searchlights from Dover Harbour, and there are many cases in which excess of glare would be a drawback.

A searchlight which is serviceable at a distance of three or four miles, therefore, is not necessarily the best light for searching distances of, say, 500 to 1,000 yards. Recently I have been experimenting with searchlights for river purposes, and I find that incandescent oil lighting is admirably suited for such work, since the glare is less and objects can be distinguished at a moderate distance far more readily than with sources of very high candle-power and intrinsic brilliancy.

With regard to the atmosphere, this is a subject which has not been sufficiently investigated. The penetrating power of searchlights is, as stated by Mr. Ledger, greatly obstructed by fogs and mists, and in this case the colour of the light seems to play a somewhat important part. Some fourteen or fifteen years ago, when the system of lighting with which my name is associated was first taken up by the Trinity House Authorities for the lighthouses, a series of experiments were made at the High Lighthouse at Lowestoft (which was the first British Lighthouse to be equipped with this system), and it was found that during a very heavy mist the light was sufficiently strong to throw distinct shadows on Gorleston Pier, a distance of, I believe, eight miles. I understand that the lamps previously used were incapable of throwing the light so far in misty weather. This peculiar quality of the incandescent oil light has made it very serviceable in lighthouse illumination. About the same time, an experiment

was made in the lighting of one of the London streets, viz., Portland Place, and it was also noticed by the residents and the police authorities that during some of the very severe fogs prevalent at that season objects were far more distinguishable under the incandescent oil light than in any other part of London. The late Lord Roberts, who at this time was a resident of Portland Place, remarked himself this particular quality of the light. He stated to one of my employees that during the densest fog he was able (without difficulty) to read his papers in his front rooms facing the street, from the oil lamps which were erected in the centre of the thoroughfare.

It has been claimed that this is due to the presence of the red and yellow rays. There is a great field here for further investigation. For many years I have believed that we should ultimately be able to produce a light which would penetrate fogs for a very considerable distance, and render navigation and traffic as safe as in clear weather.

A further illustration as to the utility of the incandescent oil light in fogs was shown in the testimony given by some of the officials of the steamship "Suevic," which was wrecked some years ago near the Lizard. The Lizard Lighthouse was at that time equipped with the electric light system, and the "Kitson" Oil Light was used as an emergency light. One of the officers of the wrecked steamer stated that it was his belief that if the oil light had been burning on the particular night in question his vessel would not have met with the accident which led to her becoming a wreck. Whilst the electric light was imperceptible, he was able to see what afterwards was discovered to be an oil light burning in a cottage near the coast. The development of the searchlight will, in my judgment, play a very important part in our coast defences in the future, and there is no country in the world which would benefit more by the discovery of a light which would enable our vessels to be seen clearly for a distance of at least 2,000 yards in the heavy fogs with which this country is afflicted.

SEARCHLIGHTS USING HALF-WATT LAMPS.

In a recent number of the *Electrical World** there is a reference to the applications of half-watt lamps for searchlights. With lamps of this type having a short stable filament and yielding 1000—2000 candle-power, a powerful beam can be obtained, and the power required is so small that the whole equipment can be mounted on an automobile of moderate size or, in case of need, carried for a considerable distance by men or horses. The article continues :—

"A beam of light intense enough to detect the movement of hostile forces at 2,000 yds. should be of great value, particularly when the apparatus is light enough to be readily shifted about in the trenches so that it may reappear in a diferent spot long before hostile artillery is able to get its range. Night attacks seem to be especially frequent, and sufficient light to disclose them even at a distance of a few hundred yards gives a chance for action in a period long enough to insure a repulse. Such search-lamps ought to be particularly valuable in repelling airship attacks, since their range is certainly adequate, except in very thick weather, when airships themselves are likely to go astray, to pick up an object the size of a Zeppelin at any height attainable by such craft. With an incandescent search-lamp mounted on a fast automobile and followed by another with machine guns it ought to be possible to keep an airship once detected under fire for a long period. For such military uses the incandescent search-lamp seems peculiarly fitted, and it will be rather surprising if it does not come into considerable use."

* *Electrical World*, December 26th, 1914.

Electric lamps, Arc

SOME NOTES ON THE CONDITIONS DETERMINING THE CANDLE-POWER AND STEADINESS OF LARGE CURRENT ARCS FOR SEARCHLIGHTS.

By MRS. HERTHA AYRTON.

I BELIEVE I can most usefully contribute to this discussion by giving the results of my own experience in the course of three investigations. These were undertaken for the purpose of finding out under what conditions such large-current arcs as are used for searchlights will emit the maximum of light for a given current while remaining always perfectly steady. The first two were made for a public authority, the third, of the same type though for a different purpose, for a cinematograph company.

The first series of experiments, made in 1905-6, was somewhat in the nature of a trial trip. For the second, carried out in 1906-7, the specified current was 120 amperes, and the lamp to be used, a horizontal-carbon automatic-feed Crompton lamp in a 36-in. projector, was supplied by the Authority. I was required to find the best carbons to use in such a lamp and to state what voltages at the terminals of the generator and the lamp should be employed in order to obtain a perfectly steady arc giving the largest possible amount of light with the carbons I specified. The third series was carried out in 1913, and in this the only thing specified was the current of 85 amperes; in everything else I had a free hand. The general conclusions arrived at as a result of all three investigations are given below.

CONSTANT VOLTAGE AT TERMINALS OF GENERATOR.—It cannot be too strongly insisted on that you cannot hope to maintain a steady arc unless the P.D. at the terminals of the machine is very considerably higher than that required at the terminals of the lamp. Only within the last year I have seen attempts made by a responsible body to maintain an arc requiring quite 60 volts with a dynamo that could only give 65 volts. The pitiable results of alternate hissing and extinction were quite bewildering to the operators who had been set the impossible task. If such a low voltage dynamo were the only one obtainable, then the carbons and current used should have been altered to suit this condition; but authorities have not yet learnt the lesson that the arc is a rebel and cannot be coerced. A very good rule is for the generator to be capable of giving a constant voltage from 30 per cent. to 33 per cent. higher than that required at the terminals of the lamp. In my second investigation, for instance, in which 120 amperes was specified, I found that I got the maximum of light with an arc taking 70 volts at the terminals of the lamp, and that to have this perfectly steady needed a constant 95 volts at the terminals of the machine. This was using a solid positive carbon. When a cored positive was used, the light given out was less, but the lamp voltage was then 60, and the dynamo voltage 80; the proportion, therefore, was much the same.

LAMPS.—The Crompton horizontal-carbon automatic-feed lamp worked remarkably well but for two easily-remedied defects—the one connected with the iron horse-shoe mentioned by Mr. Ledger and the other with the automatic-feed mechanism. With horizontal carbons, when they are placed with their axes in line, the upper part of the positive burns much faster than the lower, owing to the rising of the flame. The crater than burns in a slant and a "lip" forms below, giving rise to unsteadiness. The object of the horse-shoe, which becomes magnetised by the burning arc, is to send the flame down and keep it well between the carbons, so that the crater shall burn vertically. I found, however, that it was

impossible to maintain a really steady arc with the horse-shoe in position, and so I discarded it, and tried placing the negative carbon so low that the lower part of the positive burnt as fast as the upper. This was quite successful. Without the magnet, when the lower surface of the negative is placed about on a level with the lower surface of the positive, the crater burns in a perfectly vertical plane and the arc is quite steady. The question of the exact level is a matter of trial with each pair of carbons, but it soon becomes evident whether the crater is burning away more above than below or *vice versa*, and one of the carbons is then raised or lowered to set matters right.

The second defect in the Crompton lamp had to do with the feeding mechanism. This fed the carbons when the voltage at the terminals of the lamp reached any given P.D. for which it was adjusted. As the coils of the mechanism warmed up, however, the feeding took place at a higher and higher voltage, so that the arc got longer and longer each time before the carbons were fed. The remedy was to watch the voltmeter and readjust the feeding mechanism from time to time. The difficulty would be hardly worth mentioning but that operators are apt to forget that the amount of light given out and the steadiness of the arc both depend upon this voltage.

Horizontal carbons are not the best for searchlights, however; the negative obscures too much of the light of the crater; inclined carbon lamps also are unsuitable, I consider, both for them and for cinematograph work. There are several angle lamps on the market, but as I could find none that was satisfactory I had one made early in 1913 so that I could alter the angle between the carbons within a wide range, and all my subsequent experiments were made with that lamp. I finally came to the conclusion that the best results were obtained with the positive carbon horizontal and the negative making an angle of about 150° with it. The inventor of the ingenious lamp described by Mr. Eck seems to have gone through the same process with much the same result.

It is usual to attach mechanisms to the lamp which enable the positive carbon to be moved relatively to the negative vertically and horizontally. In mine I had the horizontal motion given to the negative carbon, and I believe that both motions ought really to be given to that carbon, for the reason that, as the crater is the source of light, when it is once focussed it should never be moved relatively to the lens and mirror except for the inevitable feeding.

A good lubricant for all the various mechanisms of the lamp is a most important item in its smooth working. None containing oil ought ever to be used (yet the only ones on the market all contain oil, I believe) because the oil quickly becomes solidified with the heat and clogs the racks causing them to jam. The perfect lubricant is a thin mixture of turpentine and powdered black lead of the kind used to polish the domestic grate. A thin coating of this, painted with a stiff brush on to all the working parts, will keep the lamp working smoothly many hours a day for a month at a time. It was revealed to me by a clever cinematograph operator.

CARBONS.—*The Positive Carbon.* For Searchlights a solid positive carbon is to be preferred whenever it is possible to use a generator giving high enough voltage. With a good solid positive carbon the crater never cracks and breaks, there is no core to drop out, and the intrinsic brilliancy of the crater is higher. The carbon has to be larger than a cored carbon for the same current, but it burns more slowly, even in proportion to its diameter, and therefore is in every way more economical. The only disadvantage is that the light is a little more apt to move about over the crater than with a cored positive carbon, but without any hissing or sputtering or real unsteadiness following.

Negative Carbons. The choice of the negative carbon has, perhaps, more effect on the steadiness of the arc than any other single factor that can be named. The well-known desiderata are that its tip shall present only a small surface for the arc to rest upon, and, for searchlights, that the carbon shall burn away at exactly the same rate, length for length, as the positive. The search for the perfect negative carbon was by far the most

difficult part in all my three investigations. A slender solid negative burnt well but much too fast; a thick one burnt more slowly, but with such a blunt rounded tip that the arc was never steady when it had once formed. In 1905-6 I reduced the surface of the tip in two ways: I used as negative a cored carbon which had been made for a positive, so that, as the core always burnt faster than the outside shell, leaving a shallow hollow in the middle, there was only a ring of carbon at the tip for the arc to rest on. In order to make this ring even thinner, I reduced the diameter of the carbon and, to give it the necessary conductivity, to carry so large a current, I gave it a coating of copper, but a much thinner coating than had ever previously been employed. These were the first small diameter negatives for large currents ever made. The carbons I specified for the current of 120 amperes, for instance, were 38 mm. solid positive and 18 mm. cored, copper-skinned negative, the copper being 0.02 mm. thick; and the two burnt at exactly the same rate, length for length—about $1\frac{1}{3}$ in. an hour. The carbons previously used in the same lamp were 35 mm. cored positive and 26 mm. solid negative heavily coppered, so that the negative had a cross section rather more than twice as great as mine. With these carbons the arc was never steady for two minutes together.

In 1913 I devised two new kinds of negative carbons, both of which are applicable to searchlights. The first had a hard core, softer outer shell and copper skin; these are the type to which Mr. Ledger referred, only he mentioned a non-essential copper core and forgot the essential copper skin. The characteristic of these hard core carbons is that they burn always with a slender point of the hard core protruding; it is this that makes them burn so steadily. The distance to which the point protrudes and the length of the bare carbon tip both depend on the thickness of the copper skin, and this therefore determines both the steadiness of the arc and the rate of burning of the carbon; but a copper or coppered core is actually deleterious, for it has the effect of colouring the arc.

The second of the new types of negative is the best of all, because it is the simplest. It is a hollow tube of rather soft carbon stopped up at the butt end to prevent the air whistling through, and with a copper skin. In this carbon also the thickness of the copper determines the length of the bare tip, and therefore the rate of burning. I find that one of these carbons 13 mm. in diameter with a hole 3 mm. in diameter and a coating of 0·03 mm. of copper burns with perfect steadiness at the same rate as the cored positive carbon 25 mm. in diameter. I used with it a current of 85 amperes.

The Shaping of the Carbons. In 1895 I published in *The Electrician* an article with numerous illustrations showing that the burning ends of the carbons acquired a distinctive shape which I called the "normal" shape for each current and length of arc with which they were burnt. This fact, which was discovered by Prof. Ayrton and his students, and to which I devoted the whole first chapter of my book, "*The Electric Arc,*" has become so much a matter of common knowledge that I was a little surprised to hear that Captain Ohnstad had re-discovered it in 1914. When it is remembered that if a constant current and length of arc are maintained the voltage, as we showed,* changes continually till the carbons have acquired their normal forms, the importance of their being manufactured to those forms to start with will be realised. I found, for instance, with the Crompton lamp, that the carbons could start being automatically fed in from two to four minutes after the arc was struck, if the carbons were normally shaped, but that they had to be hand fed for fully 40 minutes before the mechanism could be started if they were shaped as they usually come from the manufacturers, because during all that time although the distance between the carbons and the current were kept constant, the voltage changed continuously.

Waste of Carbons. While on the subject of carbons I must mention the waste entailed by the present plan of throwing away the used ends while they are still several inches long. This is not only wasteful in itself, but in field searchlights, for instance, and in possible aeroplane searchlights, where the saving of weight

* *The Electric Arc*, p. 112 *et seq.*

is a great consideration, it is highly important that the practise should be altered. I have devised a very simple supplementary holder in which all such ends can be placed, and burnt so that, at most, an inch and a half remains.

LAMP ENCLOSURE.—It is very necessary that the lamp enclosure should be symmetrically ventilated as regards the two sides, and that there should be no back opening. I found I could not get a steady arc in the Crompton lamp till I had placed a sheet of asbestos in the opening at the back of the barrel. The side ventilation was perfect, but this opening gave rise to great trouble. For cinematograph work I have devised a lamphouse with double walls, the inner of wire gauze and the outer of asbestos separated by distance pieces made so that there is a constant flow of cold air between the two sets of walls, which carries most of the heat from the arc well up away from the operator. It is so light that it would, I think, be applicable, with a lens only and no mirror, for searchlights watching for aeroplanes, and for field and aeroplane searchlights.

AMMETER, VOLTMETER AND VARIABLE RESISTANCE.—All the precautions taken to ensure the possibility of a good steady arc will be useless unless the operator is allowed to have what may be called the right tools for his part of the business. Both a good ammeter and a good voltmeter are indispensable, and even they are of no avail unless they are placed where he can easily read them at the same time that he is attending to the arc —if, for instance, they are behind him or hidden in any way from him, they may as well not be there, and yet neither of these cases is unheard of. He must also have a variable resistance well within reach, not only to put in when he starts the arc, but also for bringing the current back to its right value when any accidental disturbance takes place. It ought to be unnecessary to mention these precautions, but it is not.

Again, it is well known that if the carbons get out of line, so that the crater burns on one side, a hissing unsteady arc is almost inevitable ; yet the operator is not usually allowed to touch the handles that bring them into line, or, if he is, they are inside the lamp enclosure, and he has to burn his hands by manipulating screws that are quite close to the arc. It is absurd to expect him to keep the arc steady under such circumstances. *All* the handles that move every part of the mechanism of the lamp should, on the contrary be cool and easily got at, and he should be trained to use them with discretion.

Finally, I am afraid I must disagree with my friend Mr. Trotter as to the kind of arc to be aimed at. A humming arc is too near a hissing arc ; in fact, it is in the first stage of hissing. The perfect arc is a silent arc, and if you cannot get it, you must get it as silent as you can.

I must apologise for mentioning so many of my own devices, but as they were evolved just because I found they were needed, it has been impossible to help referring to them.

THE ARC UNDER HIGH AIR PRESSURE.

The *Electrical World* for January 30th contains a summary of some interesting researches on the arc by Prof. O. Lummer, of Breslau. It appears that the temperature of volatilisation of carbon, and therefore the intrinsic brilliancy of the arc crater, is a function of the pressure of the surrounding air. Ordinary fluctuations in barometric pressure do not affect it greatly, but with a pressure of 22 atmospheres Lummer found that the surface brilliancy was as much as 23 times the value under ordinary conditions. At this enormous pressure he estimates the temperature of the crater to be as much as 6,000 degrees absolute, which is not far removed from the reputed temperature of incandescence of the sun.

In these researches Prof. Lummer used special impregnated carbons. The result is certainly an interesting one from a scientific standpoint, as well as having possible important practical applications for searchlights, and deserves to be investigated in this country.

Searchlights

PRACTICAL AND THEORETICAL NOTES ON PROJECTORS.

By A. P. Trotter.

The actual working and use of a searchlight can be learned in a few practical lessons. Knowledge of the theory will be of little help. Acquaintance with the thermodynamics of internal combustion engines or of the design of gear teeth does not help anyone to drive a car.

Practical Hints.

My own experience has been chiefly with the Crompton automatic lamp. When this is in good order there is nothing to be said about it: it looks after the arc, hour after hour, keeping it in perfect adjustment without any attention. If it has been misused, more directions are needed than can be given in this article, and to understand the matter needs some little acquaintance with electrical matters. A large number of hand-fed lamps are in use, and a few elementary hints may be given on running them, based on my experience 15 years ago.

For the purpose of keeping a steady arc it is necessary to have a resistance in series with it. This has an incidental advantage that the carbons may be short-circuited without burning anything up. The carbons should be thoroughly dry and firmly fixed in line. Close them together and snap the switch to see if there is a short circuit. If there is not, the cables and resistance will carry the big current; if there is, the fuse will blow, and the short must be looked for. If not, close the switch and open the carbon, slowly. Until they are well hot they will not hold a long arc, and the arc will go out if lengthened too quickly. A short arc will hiss, a rather longer arc will hum, and a longer one will run silently. If too long the crater (the bright face of the larger carbon) will become uneven and the arc will wander about, burn irregularly, spoil the shape of the carbons, and go out. The shortest possible silent arc or low humming arc is best. If the positive (the larger) carbon burns with a tail or a skew face, bring the carbons together to give a roaring or hissing arc, but do not let them touch. If hissing is allowed to persist, a mushroom will grow on the negative and interfere seriously with the light. It will burn off if the carbons are separated. It is better to break the arc by separating the carbons than to use the switch. When the carbons burn away to about 3 inches they must be changed. To do this quickly without burning one's fingers is a matter of practice.

In quiet surroundings the best guide to the best length of arc is a low hum. In hand feeding, the handle may be turned until the arc just hisses, and then turned back a little. Experience will show how often feed is needed. Another way is to watch the ammeter and voltmeter.

The searchlights in London are being run on 200 volts. There is therefore a large resistance in series, and this makes it easier to keep a steady long arc. Hissing under these conditions may occur with an uneven or skew arc of considerable length. Practice alone enables a steady one to be maintained.

Theoretical considerations.

In its proper place, and with the necessary qualifications and limitations which mathematicians are sometimes apt to overlook, the theory is interesting, and of course, for the design of projectors, is essential. I was asked recently whether one of the searchlights which are being used in London could burn a hole in a haystack at half a mile. This question was evidently inspired by a slender acquaintance with theory. It is conceivable that a mirror could be made with sufficient accuracy, but the heat would have to be concentrated on a patch of not more than 2 inches or 50 mm. diameter at 805 metres. With a 90/42 projector, that is, with a mirror 90 cm. diameter and 42 cm. focus, the diameter of the crater of the arc would have to be only

$(50\times420)/805000=0{\cdot}026$ mm. or one thousandth of an inch, and it would be impossible to use a current of 120 amperes.

Theory tells us that the light emitted from a focal point of a paraboloidal mirror is reflected as a parallel beam. But in practice we are not dealing with focal points, but with arc craters as large as a shilling, say 22 mm. in diameter. The middle part of a 90-cm. or 36-inch mirror of 42 cm. or 16½ in. focus has at the centre a radius of curvature of 820 mm. or 33 in. The outer parts have a flatter curve. The depth is about 115 mm. 4½ in. Fig. 1 shows such a mirror. The

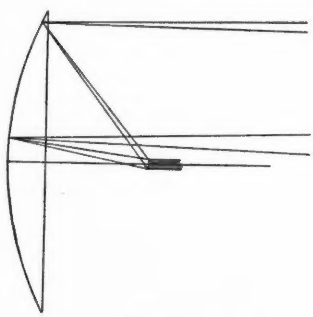


FIG. 1.

crater, 22 mm. in diameter, subtends an angle of about 3 deg. to a point at the middle of the mirror, and about 1¼ deg. to a point at the edge. In practice the divergence may be taken as an average of 3 deg. At half a mile the beam is about 139 feet in diameter. If an attempt is made to concentrate the rays by moving the lamp away from the mirror, the outer rays which have less convergence will cross, and the beam will be irregular. The best place for the crater is the focus, and the natural divergence is generally the best. It is possible that for showing up a flotilla of aircraft a divergent beam produced by racking the lamp in, might be useful.

The theory of projectors has been discussed by F. Nerz, Prof. Blondel, and Capt. Bremner. Prof. Blondel says that "the useful effect of a projector may be defined (1) by the luminous intensity (or, as we say, candle-power) at a great distance, measured in the axis of the beam, which determines the limit of range with which the projector can, according to the state of the atmosphere, produce a sufficient illumination; and (2) the angle and homogeneity of the beam which determines the area usefully illuminated." In practice, the range is a rather indefinite quantity. It is the distance at which objects can be recognised by means of the beam. So much depends on the colour and size of the object and of its background, and on the atmospheric conditions, that the range of a searchlight must be left to the practical judgment of an experienced man, and can hardly form a matter for calculation.

The candle-power of searchlights and lighthouses is often described in large figures, but they mean little. A parallel beam has no measurable candle-power. Such a beam produces the same illumination on a surface perpendicular to the axis, at whatever distance it is placed. With a convergent beam the expression candle-power is meaningless. If the rays from a projector all had a uniform divergence of 3 deg. they might be considered to be emitted from a point source behind the mirror at a distance of 19 times its diameter.

The mirror acts, along the axis of the beam and through a small angle with that axis, as a source of light. Under laboratory conditions the coefficient of reflexion might approach 85 per cent.—in practice it is likely to be nearer 75, and the transmission through the window will bring the light down to about 65 per cent. A mirror, says Prof. Blondel, behaves at a great distance exactly as a plane incandescent surface having an intrinsic brilliance the same as that of the source of light, multiplied by the coefficients of transmission and reflexion. In 1894 I found that the crater of an arc gives under best laboratory conditions 170 candles per sq. mm. Prof. Blondel found a similar value. In practice it will not average more than 120 over the whole crater. Each square millimetre of the mirror may be assumed to have a brilliance of 120 candles, and a 90 cm. mirror gives therefore about 50,000,000 candle-power.

A paradox lurks here. A paradox is generally the result of unsound reasoning. This calculation is based on candles per square millimetre of the crater, and not

on the total candle-power. It would therefore hold good if the positive carbon were the size of the lead of a pencil with an area of one square millimetre and a candle-power of 120. With a 90 cm. projector a positive carbon of 32 mm. diameter is generally used, giving a crater rather less than the full diameter, 20 mm. dia. and 314 sq. mm. area, and a candle-power of 38,000. If this reasoning is sound, the candle-power of the beam is independent of the candle-power of the lamp. The mistake is in the use of candle-power to describe the useful effect of a projector. If when viewed from a distance each square millimetre appears full of light, nothing can make it more full except an increase in the intrinsic brilliance of the crater.

Increasing the area of the crater increases the divergence. The candle-power remains the same, and the flux of light is increased. The polar curve for a projector with a small crater, giving a divergence of 2 deg. and for the same projector with a crater of twice the diameter of the first, but giving the same candle-power in each case, is shown in Fig. 2.

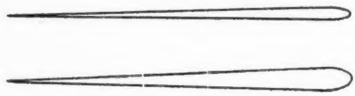


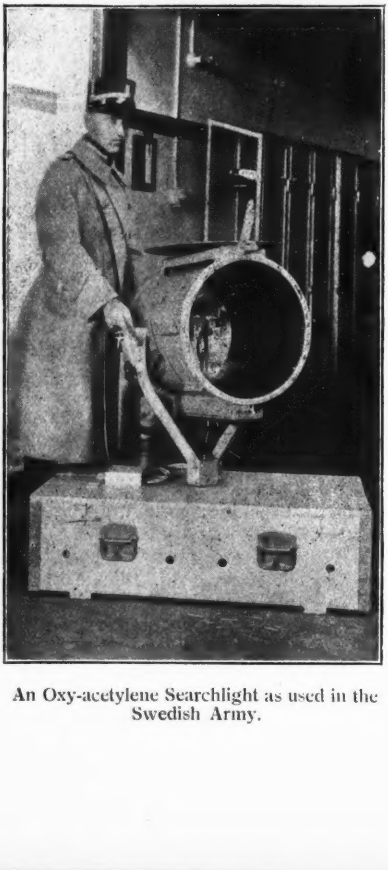
FIG. 2.

The flux of light from the crater and the flux of the beam may both be calculated, but it is hardly worth while, on account of the uncertainty of the amount of light obstructed by the negative, and the period which may have elapsed since the mirror was polished. A candle-power of 50 million will give an illumination of about 7 foot-candles at half a mile, and this on a disc of 140 ft. diameter is equivalent to about 100,000 lumens.

THE OXY-ACETYLENE SEARCHLIGHT.

A CORRESPONDENT sends us some particulars of the oxy-acetylene searchlight which is being widely adopted in the Swedish Army.

This apparatus employs a pellet of ceria on which the oxy-acetylene flame is concentrated. The standard form of searchlight is equipped with cylinders containing about 1,000 litres of dissolved acetylene and about 1,100 litres of compressed oxygen. While in use about 40 litres of acetylene and 40 litres of oxygen are consumed per hour, so that the searchlight could be used for about 20 hours without replenishing. The searchlight is stated to give about 1,500,000 candles.



An Oxy-acetylene Searchlight as used in the Swedish Army.

A METHOD FOR DETERMINING THE RANGE OF SEARCHLIGHTS.

Light projection

By Prof. A. Blondel.

The "range" of a projector is the distance at which one can distinguish an object illuminated by it. The range depends on the transparency of the atmosphere; the dimensions of the object illuminated; the colour, form and nature of the surface of this object; the degree of contrast with surroundings, &c. The problem of determining the range as a function of these various quantities is much more complex than is generally believed. It is necessary to take account not only of the physical and geometrical properties of the beam of light, but also of the influence of telescope, glasses, or spectacles and of the physiological idiosyncrasies of the observer's eyesight.

I propose to discuss the problem successively (*a*) from the purely physical standpoint (illumination produced) and (*b*) from the physiological standpoint (visual acuity).

Nomenclature.

Let us denote by—

- I, the ***luminous intensity*** of a source equivalent to the searchlight beam, in mega-candles.
- x, x_1, respectively the ***distances*** from the mark or object illuminated to the projector and the observer, in kilometres.
- $l=x-x_1$, the *difference between these distances.*
- E, the ***illumination*** received in the neighbourhood of the object, (*i.e.*, the luminous flux received by a plane surface, divided by its area).
- a, the ***coefficient of transmission*** of the atmosphere (the fraction of the incident light that traverses a thickness by 1 kilometre of air).
- g, the ***magnification*** of the glasses used by the observer.
- k, the ***coefficient of transmission*** of the optical system of these glasses.
- $R=\log\left(\frac{k.d^2}{p^2}\right)$, a function for the glasses.
- d, diameter of the ocular image of the objective lens of the glasses.
- p, diameter of the pupil-aperture in the eye.
- E_0, minimum illumination in lux required to enable the illuminated object to be distinguished by a person having normal acuteness of vision.
- $H=\log E_0$, another empirical constant.
- V, *acuteness of vision* factor.
- b, a coefficient depending on the dimensions of the illuminated object.
- B, an empirical coefficient, specifying the effect of *form, colour* and *contrast* of object, in regard to surroundings.
- $L=Bb$, an empirical constant defining the distance at which vision objects can be perceived by a person of normal acuity under an illumination ten times as great as E_0.

Illumination of Object.

The illumination would be $\frac{I}{x^2}$ except for the atmospheric absorption. The actual illumination will be reduced to

$$E=\frac{I}{x^2}\cdot a^x,$$

a being the coefficient of transmission, as mentioned above, and less than unity. Transposing into logarithms we have the equation:

$$\log E=\log I+x\log a-2\log x.$$

But this statement of the illumination of the object is not sufficient to determine its *visibility*, which depends on the apparent brightness[1] of the object. The

[1] Several observers have been led into the error of supposing that the apparent brightness of an object can be expressed by some such formula as:—

$$\frac{I.a}{(x+x_1)^2} \quad \text{or} \quad \frac{Ia^{x+x_1}}{x^2x^2_1}$$

In the first case it is assumed that the brightness varies according to the inverse square law. These formulæ are entirely incorrect, for they do not take account of the fact that the acuteness of vision falls off as the distance increases.

visibility is therefore affected by the reflecting power of the object illuminated and on any factors operating between the eye and the object and tend to reduce its brightness, such as the interposition of a greater or less thickness of air, and also, as a rule, spectacles or glasses used by the observer.

In practice the minimum illumination necessary to enable an object to be seen depends on its colour and form and the texture of its surface. The intensity *I* is known. It may be measured direct photometrically,[1] or it may be calculated approximately in the case of an electric arc light by multiplying the projected area of the crater facing the mirror by the intrinsic brilliancy of the arc (which usually varies between 150 and 200 candles per square millimetre, according to the current density) and also by a factor allowing for the absorption of the mirror and the glass window.[2]

The transmission coefficient is generally less than the value 0·973 given by Bouguer for a very clear atmosphere. On land it depends chiefly on the amount of dust and water vapour in the atmosphere in the quarter through which the projector's rays are received, and can only be determined by very methodical observations. At sea this coefficient is much better known as a result of investigations in the lighthouse service, which has prepared tables indicating the conditions existing on various portions of the sea coast (the Channel, Ocean, Mediterranean, etc.).

Table I., for example, indicates the proportion of the year (denoted by "*n*") during which the coefficient of transmission is greater than the value mentioned above.

TABLE I.—VARIATION IN TRANSMISSION COEFFICIENT DURING THE YEAR IN FOUR CHIEF COAST REGIONS OF FRANCE (AFTER ALLARD).

Proportion of the year *n*.	Corresponding to Mean Transmission Coefficients.							
	Channel Coast.		Britanny and Cotentin midway between the Channel and the Atlantic.		South-west Coast (Atlantic Ocean).		Mediterranean.	
	p.	*a*.	*p*.	*a*.	*p*.	*a*.	*p*.	*a*.
0	10·00	1·000	10·00	1·000	10·00	1·000	10·00	1·000
$\frac{1}{12}$ or 0·083 ..	8·48	0·962	8·48	0·962	8·48	0 962	8·55	0·964
$\frac{2}{12}$ or 0·167 ..	8·06	0·948	8·06	0·948	8·09	0·949	8·13	0·950
$\frac{3}{12}$ or 0·250 ..	7·75	0·936	7·79	0·938	7·84	0·940	7·88	0·941
$\frac{4}{12}$ or 0·333 ..	7·48	0·925	7·58	0·929	7·69	0·934	7·78	0·937
$\frac{5}{12}$ or 0·417 ..	7·22	0·914	7·38	0·921	7·51	0 926	7·71	0·935
$\frac{6}{12}$ or 0·500 ..	6·93	0·900	7·15	0·910	7·31	0·918	7·65	0·932
$\frac{7}{12}$ or 0·583 ..	6·58	0·880	6·88	0·897	7·07	0·906	7·60	0·930
$\frac{8}{12}$ or 0·667 ..	6·24	0·860	6·50	0·876	6·80	0·893	7·54	0·928
$\frac{9}{12}$ or 0·750 ..	5·77	0·826	5·98	0·842	6·40	0·870	7·40	0·922
$\frac{10}{12}$ or 0·833 ..	5·12	0·770	5·35	0·791	5·77	0·826	7·12	0·909
$\frac{11}{12}$ or 0·917 ..	4·08	0·644	4·33	0·678	4·67	0·722	6·55	0·979
$\frac{12}{12}$ or 1·000 ..	0·00	0·000	0·00	0·000	0·00	0·000	0·00	0·000

p is the limiting distance, measured in kilometres, at which one can still see distinctly a luminous source with an intensity equal to $\frac{1}{10}$ candle A knowledge of *p* thus gives a measure of the coefficient of transmission *a*.

[1] Such measurements are rendered particularly simple by the use of a portable "lux-meter," which enables the illumination to be determined with precision down to $\frac{1}{10}$ lux.

[2] See A. Blondel, Théorie des Projecteurs Electriques de Lumière (Octavo, 1894, 2nd edition).

Now let β be the coefficient of diffuse reflection of the surface.

The illumination received by the surface is

$$E=\frac{Ia^x}{x^2}$$

The apparent brightness of the object, as seen by the observer, is

$$i=\frac{\beta.E}{\pi}=\frac{\beta.Ia^x}{\pi x^2}$$

which is independent of the distance if the transmission coefficient a=1 (since the quantity of light received by the eye raises inversely as the square of the distance, but so also does the area of the retinal image). Allowance must in practice be made for the effect of absorption in the atmosphere. Assuming that the diffusion follows Lambert's law, so that the brightness is independent of the angle from which it is observed, one can finally write for the value of the apparent brightness of the screen, the expression :—

$$i=\frac{\beta.Ia^{x+x_1}}{\pi x^2}$$

Denoting by E' = the "apparent illumination" of the screen, we can put the equation into a form more convenient for practice, thus :—

$$E'=\frac{Ia^{x+x_1}}{x^2}=\frac{Ia^{2x}a^{-l}}{x^2}=\frac{1}{a^l}\cdot\frac{Ia^{2x}}{x^2}$$

whence $\log E'=\log I+2x\log a-2\log x=l\log a$.........(2) l being the difference in the distances of the projector and observer from the object illuminated.

As will appear later the above equation is easily expressed in graphical form.

For each variety of object there will be a certain minimum illumination needed.

If one knows the minimum illumination which must be available in order to distinguish clearly objects having a reflecting power β, the above equation will determine the range; conversely it enables us to calculate the candle-power, I, necessary to realise a minimum illumination E_{min} at a distance, x, if one knows the difference in distances, l.

In this connection it is interesting to note the following values for the reflection coefficients of surfaces, similar to those encountered in practice :—

	Coeff. of Reflection.
White blotting paper	0·7—0·8
Fresh snow	0·78
White cardboard	0·6—0·7
Whitewashed wall, clean	0·5
" " dirty	0·2—0·25
Plank of deal wood, clean	0·4
" " " " dirty	0·2
White sandstone	0·24
Clay	0·16
Muddy and trodden earth	0·08

There is no necessity to make use of a great number of different values for a, for this quantity is not known with any great precision, and when it has fallen to a low value the atmosphere loses all transparency; one might, for example, work with values of 0·5, 0·6, and, under the best conditions, with 0·7, 0·8, 0·9 and 0·97.

Effect of Glasses.

When an observer is very distant he will probably make use of glasses,[1] resulting in a certain magnification of objects which is favourable to visual acuity, but on the other hand entails a corresponding diminution in apparent brightness.

In the case of a Galilean telescope the diminution in brightness is diminished by the transmission coefficient, k, of the lens system, including the absorption by the lenses and the loss in reflection from the various surfaces traversed. In the case of the prismatic glasses used in the modern field glasses the coefficient of absorption, k, is much greater and must be multiplied by the quantity $\frac{d^2}{p^2}$, d being the diameter of optical aperture of the system, and p, that of the pupil (p=approx. 8 mm. by night). The factor of reduction is then $k\frac{d^2}{p^2}$

The coefficient $k\frac{d^2}{p^2}$ may be determined experimentally with sufficient exactitude by observation of the brightness of a white screen illuminated with approximate uniformity by means of

[1] The acuteness of vision attained with field glasses is very much greater than that obtained by the aid of spectacles.

a lamp placed behind the observer. The eye of the observer should be furnished with an artificial pupil of 2·5 mm. aperture. One then asserts successively in between the eye and the screen the telescope (focused on infinity) and a weak glass of varied thickness, which can be adjusted until the diminution in brightness is the same as that caused by the telescope. By alternately introducing the telescope and the graded glass the point of balance is readily estimated and from a knowledge of its qualities the absorption of the telescope can be readily determined.

For night observations one should always choose a glass in which d is at least equal to p; but this condition is rarely fulfilled and in general the diminution in brightness so occasioned goes far towards balancing the magnifications.

Realisation of the desired Acuteness of Vision.

We have seen that the illumination, E, must enable the acuteness of vision[1] to suffice for the perception of detail. Whatever be the colour of the rays[2] of light from the projector (or, what amounts to the same thing, the colour of the object illuminated) acuteness of vision varies as a function of the illumination, or rather of the apparent brightness, of the illuminated object, which, again depends on its reflecting power. Moreover this function the same law if one designates E_0, the minimum illumination necessary for distinct vision, as unity. This theory, first announced by Helmholtz,[3] appears to have been confirmed by the researches of Koenig.[4]

According to Koenig's curves,[5] whatever be the colour of the light the acuteness of vision, measured with respect to Snellen's types, varies as the logarithm of the illumination, following the double law of Fechner; that is to say, the relation connecting the above quantities would be two "jointed" straight lines having a different inclination, and corresponding respectively to vision by weak light ("rod vision") and vision by strong light ("cone vision"). The maximum acuity attained at weak illuminations is about 0·15. According to recent researches the point of transition from one state of vision to the other would appear to occur with a brightness in the neighbourhood of 0·05 to 0·1 candles per square metre, corresponding to an illumination on white paper of 0·25 to 0·50 lux[6]. This order of brightness is generally surpassed in the case of objects illuminated by searchlights (*a fortiori* when the country is covered with fresh snow).

Now, in actual practice, when Snellen's types are replaced by coloured objects perceived against a more or less relatively

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[1] In general, one measures acuteness of vision by the reciprocal of the limiting angle at which black type of a certain size can be seen against a white background. This angle is about 1 foot by 5 feet for a normal eye, with an illumination on mat white paper of 10—20 lux, which is equivalent to an area of 0·29 m. by 1·45 m. at a distance of 1 kilometre. If the objects to be distinguished subtend a smaller angle than the above, they cannot be distinguished. Conversely, if the angle is greater than this limiting value, a smaller illumination would suffice to make them visible, provided always, as Charpentier has shown, that a certain minimum illumination is available. The maximum acuteness under a high illumination may reach about 1·5–1·7.

[2] Nevertheless, acuteness of vision depends on the colour of objects, and the colour of the rays illuminating them. According to Langley the maximum sensibility is attained in the yellow-green and diminishes rapidly on either side of this point in the solar spectrum. But the spherical and chromatic aberration of the eye introduce complexities, and, in the case of distant objects the acuteness of vision is very low for blue rays. There is, therefore, no disadvantage in suppressing the blue rays in the spectrum of light from projectors.

[3] Helmholtz, Handbuch der physiologischen Optik. I. Aufl. p. 443.

[4] A. Koenig, Gesammelte Abhandlungen, p. 391, lines 6–20.

[5] Koenig, Gesammelte Abhandlungen. p. 388.

[6] See Percy W. Cobb (Trans. Illum. Eng. Soc. (U.S.A.), June, 1913, p. 293). According to Dow the change in the line occurs near 0·2 lux (Illum. Engin. Lond., April, 1909); Luckiesh (Trans. Illum. Engin. Society, U.S.A., April, 1912, p. 154) finds that the change is nearer 1 lux, with white paper. There is, therefore, a certain degree of inexactitude in obtaining these values absolutely and only experience can decide when the first portion of the diagram is applicable; the constants B and H will be varied according to the region on which we are working.

dark background, one should state Fechner's Law in the form :—

$$V=B\log\left(\frac{E}{E_0}\right)=B\,(\log E-H)$$

where B and H are two empirical constants, selected according to the character of the object observed, colour, background, &c., and the composition of the light illuminating them. B and H will vary according to the illumination, and the curve will consist of two broken rectilinear portions.[1]

Determination of Constants B and H.

One can determine the above constants by making a series of measurements on a day when the absorption of the atmosphere is negligible, with a projector of known intensity, producing an illumination I/x^2 on the mark observed by the naked eye (so as to avoid complications introduced by the effect of glasses). We have then the following relation :—

$$\log E=\frac{V}{B}+H=\frac{x_1}{Bb}+H, \quad \ldots\ldots(4)$$

where b specifies the dimensions of the object and b/x_1 is the angle subtended by it in radians, and $\frac{0{\cdot}00029x_1}{b}$ is the acuity in reciprocals of angles in minutes. One then makes use of a series of absorbing glasses, the values of which have been standardised beforehand, and having a known transmission coefficient, T. E can be altered at will by interposing these glasses successively in the path of the searchlight. By this means we obtain the relation :—

$$\frac{x_1}{Bb}+H=\log I-2\log x+(x+x_1)\log a+\log T. \quad (5)$$

The constant, B, which one deduces from Koenig's work, will be about 0·43 with V expressed as a function of the normal acuteness of vision; this corresponds to a length of 1·45 metres visible at a distance of one kilometer. If the range is expressed in kilometres, he illumination E is measured in lux, and the characteristic dimensions of the object, b, in metres :—

$$B=\frac{0{\cdot}43}{1{\cdot}45}=\frac{1}{3}, \text{ whence } \frac{1}{Bb}=\frac{3}{b}$$

If, for example, an object gives an acuity, $V=0{\cdot}2$ at 1 kilometre,

$$\frac{1}{Bb}=\frac{3.0{\cdot}20}{1{\cdot}45}=0{\cdot}41.$$

If we vary x_1 (by altering the position of the observer) and also T in such a manner as to obtain always just the desired visibility, we can obtain a relation between x_1 and E. By plotting $\log T$ as abscissa and the first quantity in the equation as ordinate we obtain, if $\log a$ is negligible, a straight line whose inclination gives the quantity $\frac{1}{L}=\frac{1}{Bb}$ and the intercept along the ordinate from the origin, the quantity H.

Better still, the observer could operate at different distances from the illuminated mark, inspecting the object through a double photometer with absorbing prisms, which is graduated direct in logarithms. The photometer will be regulated in such a way as to obtain at each distance the exact limit of visibility. One can thus, without varying I, construct the curve relating x_1 and $\log E$. I am at present constructing a small apparatus of this kind which could be conveniently employed on the direct vision principle; in this instrument an adaptation of the Galilean telescope may be used, and it is unnecessary to vary the candle-power of the source.

One could also operate in the laboratory with small models of ships, combatants and illuminated scenery. Thus, by using

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[1] According to other experience, notably that of P. W. Cobb, any increase in brightness in the area surrounding the actual object under observation will considerably diminish the ease with which it can be seen—if the object is itself very weakly lighted. When, however, the object is very strongly lighted (brightness above ten candles per square metre, a value never attained with projectors) an increase in the illumination of the adjacent area tends to improve its visibility. One may conclude that a white sky has the effect of diminishing acuteness of vision; however, the illumination of neighbouring objects is too weak to have any prejudicial effect, provided the moon itself does not fall within the direct line of sight. Lateral illumination of the eye of the observer by the searchlight beam may be highly prejudicial to visual acuity, especially if the light is bluish in tint.

for the searchlight a small movable lamp of known candle-power one could alter distance and illumination as in practice. The quantity $\frac{x}{b}$ will be the same for a small model reduced to the nth of the real size as for a real object placed at a distance n times as great. The graph would be constructed as a function of x and log E. (Equation 4.)

General Equation for Determination of Range.

In order to obtain this general equation it will suffice to replace E by the value of the apparent illumination, calculated as above and taking into account the effect of glasses, and to introduce into the expression for visual acuity the magnification, g, which should multiply the dimensions of the object, b.
In this way we obtain the full equation[1]:

$$\frac{x_1}{gBb}+H=\log E_1=$$

$$\log I+(x+x_1)\log a-2\log x+\log\left(k\frac{d^2}{p^2}\right)$$

Whence, replacing the last term by R, the final term of the equation, and putting between brackets (since R is always a negative quantity):

$$[R]=\log\left(k\frac{l^2}{d^2}\right)$$

one can write :—

$$\log I=\left(\frac{x}{gL}+H-x_1\log a\right)+$$
$$(2\log x-x\log a)+[R]\ldots\ldots(6)$$

Two interesting cases may be considered. If $x=x_1$ (as will be the case when both searchlight and observer are on a ship), the second term in the equation is simplified, and we get :—

$$\log I=\frac{x_1}{gL}+H+2\log x-2x\log a+[R]\quad(7)$$

Again, if $x_1=0$ (a condition which occurs when the observer is stationed quite close to the mark, and does not use glasses) :—

$$\log I=\frac{x}{L}+H+2\log x-x\log a\ldots.(8)$$

If we assume that a is known[1] the first term within brackets in equation (6) only contains a function of x_1 and the second only a function of x. Tables can therefore be prepared for these two functions in which x and x_1 are assigned various values. If in addition I and the difference $l=x-x_1$ are known the equation determines x.

(To be continued.)

[1] It is to be noted that a being >1 by definition, *log a* is always a negative quantity, the modulus of which shall be represented by [log a].

LECTURES ON ILLUMINATING ENGINEERING.

We notice that a series of nine lectures on Illuminating Engineering, by Mr. J. H. Asdell, Mr. S. G. Cranmer, and Mr. R. J. Rogers, has been arranged to take place at the Birmingham Municipal Technical School.

The lectures commenced on Tuesday, February 9th, and are to take place on successive Tuesdays at 8.30 p.m. The syllabus covers both gas and electric lighting, as well as general problems in illumination.

It will be recalled that lectures on Illuminating Engineering were arranged at several educational institutions in London recently, and we are glad to see that Birmingham is also giving practical recognition to the importance of the subject.

The fee for the course is 2s. Full particulars can be obtained from the Secretary, Mr. Geo. Mellor.

TOPICAL AND INDUSTRIAL SECTION.

[At the request of many of our readers we are again extending the space devoted to this Section, and are open to receive for publication particulars of interesting installations, new developments in lamps, fixtures, and all kinds of apparatus connected with illumination.

The contents of these pages, in which is included information supplied by the makers, will, it is hoped, serve as a guide to recent commercial developments, and we welcome the receipt of all *bona-fide* information relating thereto.]

SEARCHLIGHTS FOR ANTI-AIRCRAFT WORK.

At the present time the man in the street finds a new motive for studying the sky by night. Observations of the Heavenly Bodies cannot compare as an attraction with problematical Zeppelins, and the searchlights used for their detection have for him a more than theoretical interest. Anti-aircraft appliances are being studied as they never were before.

The **London Electric Firm** (George Street, Croydon) send us some particulars of a new pattern machine for this purpose, recently added to the other sizes and types of searchlights manufactured by this firm, and now being used for home defence. The apparatus is shown in the accompanying illustration. It utilises a 24-in. silvered parabolic mirror and revolves on ball bearings, enabling a wide sweep of beam and an elevation of as much as 90 degrees to be obtained.

These searchlights are arranged to work on 80 volts or for higher pressures with appropriate resistances.

The special feature of the new lamp is the combined auto- and hand feed, which enables the carbons to be adjusted while the searchlight is in operation. In warfarethis is considered an important point; for, should the light be extinguished for a moment, the object on which it is playing (aircraft or warship) can alter its position and make use of the period of darkness to approach closer, rendering necessary a sudden readjustment of the range of defensive guns. For defence purposes, therefore, it is vital that a continuous light, as little subject to interruption as possible, should be obtained.

VERITYS LTD. NEW CATALOGUE.

In our last issue* we drew attention to a pleasing little booklet on fixtures by Mr. George Verity. We have now before us a more elaborate publication, the enlarged 2nd edition of Vol. III. of the catalogue of fixtures just issued by **Veritys Ltd.** Its compilation must have involved a stupendous amount of work, which, however. is justified by the results. The catalogue contains over 500 pages and sixteen different sections, several of which cover a new field. We find a great variety of brackets, lanterns, chandeliers, ceiling fixtures, &c., most of them executed in traditional styles, others representing the most up-to-date "scientific" methods, and modelled mainly with a view to efficiency. The section dealing with French fixtures is perhaps one of the most complete, though to many the silk-shaded stand lamps will make a strong appeal; an entirely different field is covered in the new "Hospital Section," where practicability rather than ornament is the consideration. The avoidance of the collection of dust is a special point.

The section on indirect and semi-indirect fittings is again an interesting one. It is rather difficult to "place" fixtures of this kind in a decorative series. In principle they are essentially modern, and it is hardly possible to follow tradition to any great extent. And yet these methods of lighting have considerable decorative possibilities. We notice in the series, bowls of the moulded glass, alabaster, Holophane and other types. What, however, is a distinct novelty is the application of Wedgwood Ware to the semi-indirect system; one would imagine that in many interiors a skilful decorator might obtain some delightful colour-harmonies by combining these fittings with appropriate wall decoration. Indeed, the possibilities in this direction have hardly been sufficiently explored as yet. Another ingenious fitting is the indirect unit shown on p. 93, which can be readily lowered for cleaning purposes.

We are glad to see that the introductory leaflet issued by the company with the volume, besides referring to ornament, decoration and coloured finish, says a word or two on the desirability of screening bright lights from the eye. "Eye-comfort," it is stated, "has been the pass-word for 1914." Over-brilliancy which wearies the eye can never be allied to artistic effect.

Veritys Ltd. have shown commendable enterprise in issuing this publication in spite of the war and its attendant dislocation, thus giving practical effect to the British maxim "Business as usual." It only remains to be added that the House of Verity, founded in 1819, is British to the core.

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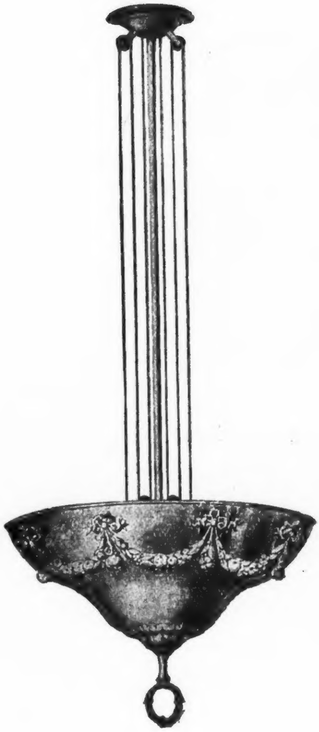
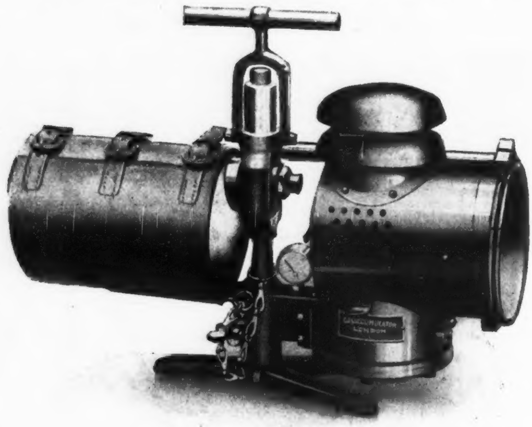
* Jan. 1914, p. 30.



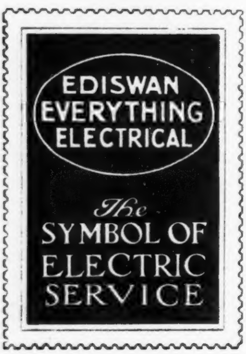
SOME STRIKING VERITYS' FIXTURES.

The left-hand upper illustration shows the new indirect fitting capable of being lowered for cleaning purposes; the upper right-hand illustration one of the Wedgewood Ware semi-indirect fittings; and the third block a three-light etched satin-finished cut glass pendant.



AN ACETYLENE SIGNALLING LAMP.

THE Gas Accumulator Co. Ltd. send us particulars of a compact signalling lamp using a small flame fed by dissolved acetylene. By pressing down a small lever a light (through the lens) exceeding 1400 candle-power is obtained. When the pressure is removed from the lever the flame is cut down to a small non-luminous pilot flame. By alternately releasing and depressing the lever very rapid signalling can take place. This has the advantage over shutter-methods of reducing the amount of gas consumed to a minimum. The whole apparatus only weighs 10 lb. 5 oz., and can easily be carried and used for night signalling by infantry or cavalry.



The above is a reproduction of the Ediswan poster stamp bearing the well-known motto: "Ediswan, Everything Electric."

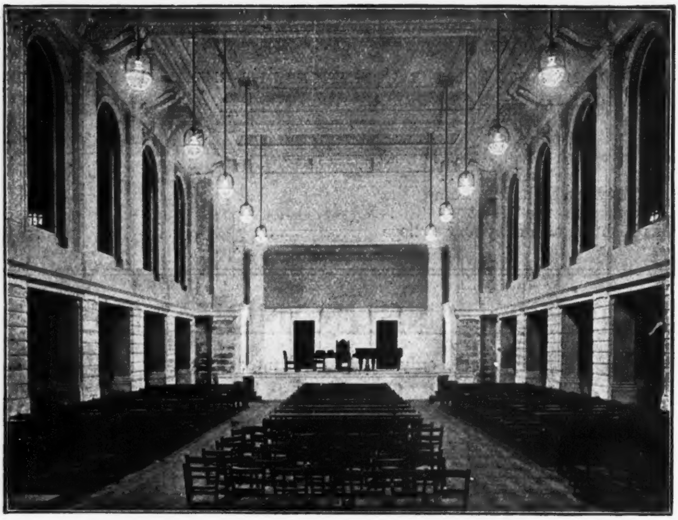
We are informed that a contract for the supply of **Royal Ediswan Lamps** for one year has been given by the Orient Steam Navigation Co.

INDEX, February, 1915.

GAS LIGHTING AT HAILEYBURY COLLEGE.

A FEW years ago a considerable number of tests of illumination in schools were carried out by the Illuminating Engineering Society, both in elementary schools and in some of the public schools, such as Harrow and Dulwich College.

The illustration shows the new hall at Haileybury College (near Hertford), which is lighted by gas. The installation consists of a series of 200 c.p. low pressure inverted gas burners, equipped with Holophane 16 in. Reflector-Hemisphere units. The burners are placed at a height of 20 feet from the floor, and



The New Hall at Haileybury College, lighted by inverted gas burners in Holophane Reflector Hemispheres.

The lighting of elementary schools can be standardised fairly easily, as the classrooms are of a more or less uniform size. In an old-established public school, on the other hand, the special nature and purpose of each room lighted needs to be considered, and some ingenuity is often needed to design appropriate illumination for large halls and large interiors.

sixteen of them are employed to light the body of the hall (100 ft. × 50 ft.).

The photograph, taken entirely by artificial light, shows the results obtained. A good feature is the uniform illumination on the students' desks, and the sources of light are high up out of the direct range of vision.